# Design Initiative for a 10 TeV pCM Wakefield Collider

## *A Community-Driven Approach*

S. Gessner, M. Hogan, B. O'Shea, SLAC

G. Ha, C. Jing, X. Lu, R. Margraf-O'Neal,
P. Piot, J. Power, ANL

E. Esarey, C. Geddes, J. Osterhoff, C. Schroeder, J. van Tilborg, J.-L. Vay, LBNL

CERN A&T Seminar
6 September, 2024

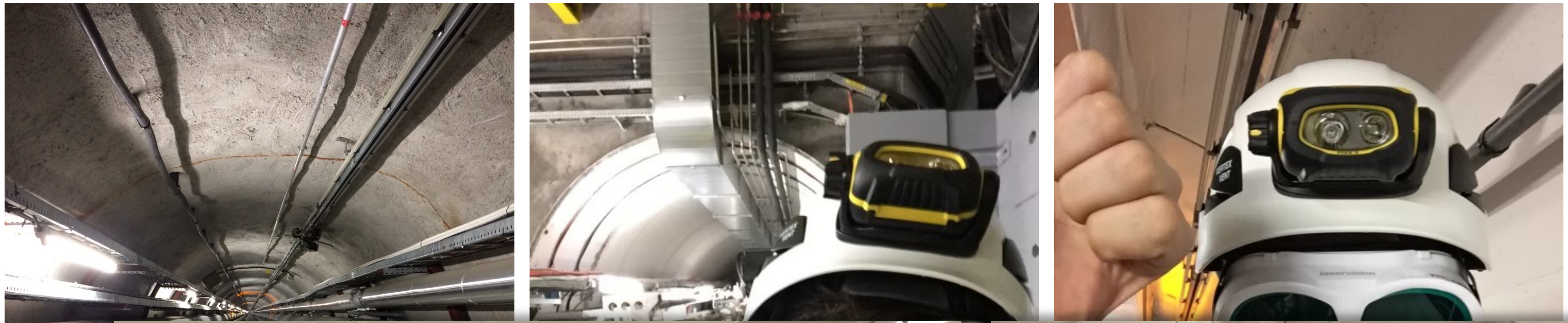
# It’s good to be back!


September 23, 2016


November 1, 2016

November 9, 2016

# It’s good to be back!



May 2018

May 2018

# The 2020-2023 Snowmass and P5 Process

2020

Snowmass 2021

Snowmass Letter of Intent submissions began Spring 2020

2021

Deadline for white papers and Community Summer Study pushed to 2022

2022

Hundreds of physicists gather at the University of Washington for CSS in 2022

2023

The P5 panel deliberates throughout 2023 and delivers the report in December

# Snowmass Implementation Task Force

There were many collider concepts put forth as part of the Snowmass process.

The Implementation Task Force (ITF) evaluated collider concepts based on:

- Physics Reach
- Technical Readiness
- Power, Complexity and Environmental Impact
- Facilities Costs and Time to Construct

~~Early~~ Career Members

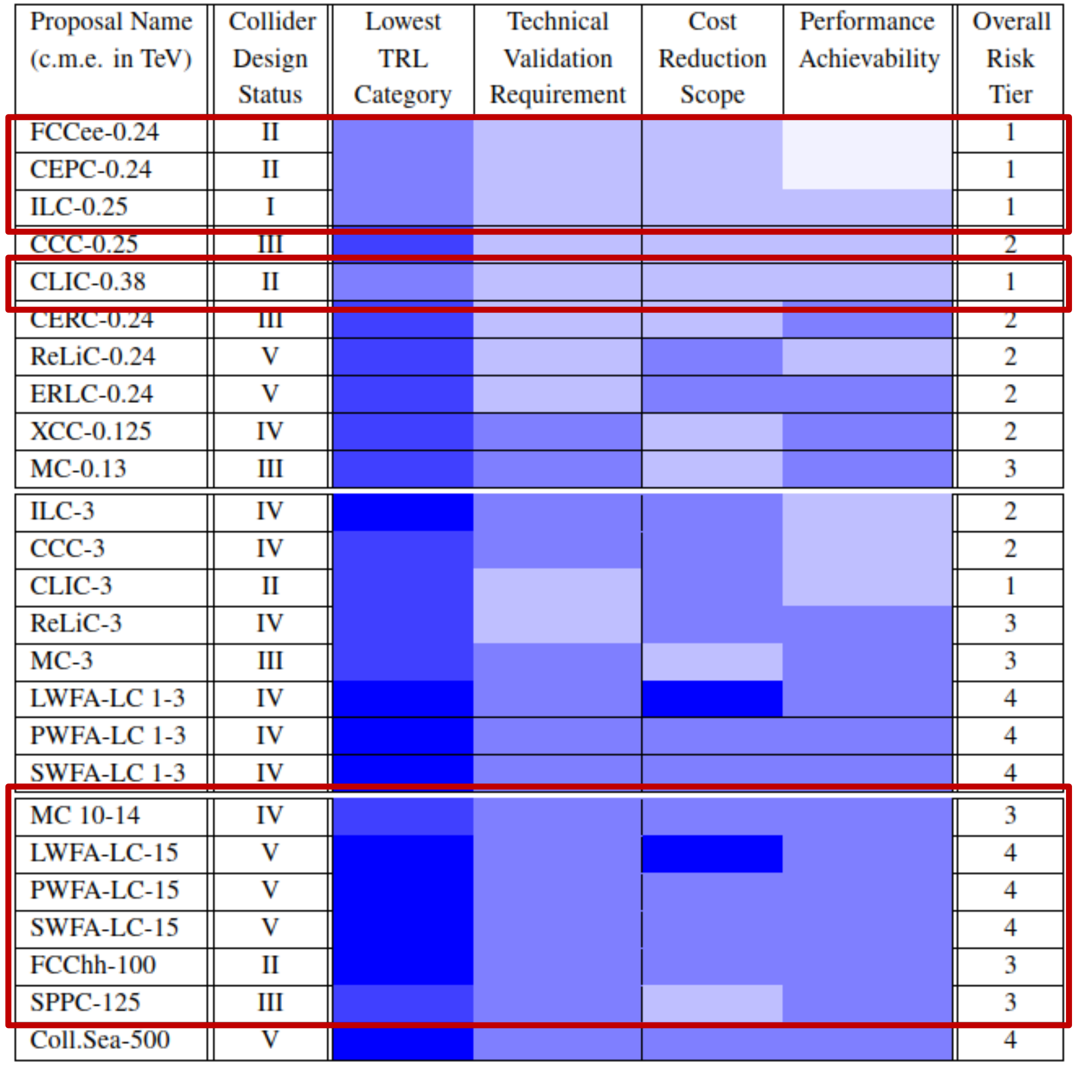
AWAKE

# Snowmass Implementation Task Force

Amongst many evaluation criteria, *Technical Readiness* and *Risk* stand out as the leading factors for which colliders the world should pursue.

FCC-ee, CEPC, CLIC and ILC are considered “low risk” options for Higgs Factories.

The HEP community is extremely enthusiastic about a discovery machine that can reach 10 TeV parton-center-of-mass, but there are no low risk options.



| Proposal Name (c.m.e. in TeV) | Collider Design Status | Lowest TRL Category | Technical Validation Requirement | Cost Reduction Scope | Performance Achievability | Overall Risk Tier |
|---|---|---|---|---|---|---|
| FCCee-0.24 | II | | | | | 1 |
| CEPC-0.24 | II | | | | | 1 |
| ILC-0.25 | I | | | | | 1 |
| CCC-0.25 | III | | | | | 2 |
| CLIC-0.38 | II | | | | | 1 |
| CERC-0.24 | III | | | | | 2 |
| ReLiC-0.24 | V | | | | | 2 |
| ERLC-0.24 | V | | | | | 2 |
| XCC-0.125 | IV | | | | | 2 |
| MC-0.13 | III | | | | | 3 |
| ILC-3 | IV | | | | | 2 |
| CCC-3 | IV | | | | | 2 |
| CLIC-3 | II | | | | | 1 |
| ReLiC-3 | IV | | | | | 3 |
| MC-3 | III | | | | | 3 |
| LWFA-LC 1-3 | IV | | | | | 4 |
| PWFA-LC 1-3 | IV | | | | | 4 |
| SWFA-LC 1-3 | IV | | | | | 4 |
| MC 10-14 | IV | | | | | 3 |
| LWFA-LC-15 | V | | | | | 4 |
| PWFA-LC-15 | V | | | | | 4 |
| SWFA-LC-15 | V | | | | | 4 |
| FCChh-100 | II | | | | | 3 |
| SPPC-125 | III | | | | | 3 |
| Coll.Sea-500 | V | | | | | 4 |

**Report of the Snowmass'21 Implementation Task Force**
https://iopscience.iop.org/article/10.1088/1748-0221/18/05/P05018/meta

# P5 Report and Accelerator R&D Priorities

Recommendation 2: Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future.

c. An **off-shore Higgs factory**, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of **FCC-ee and ILC** meet our scientific requirements. The US should actively engage in feasibility and design studies.

Recommendation 4: Support a comprehensive effort to develop the resources—theoretical, computational, and technological—essential to our 20-year vision for the field. This includes an aggressive R&D program that, while technologically challenging, could yield revolutionary accelerator designs that chart a realistic path to a **10 TeV pCM collider**.

a. Support vigorous R&D toward a cost-effective 10 TeV pCM collider based on proton, muon, or possible **wakefield technologies**, including an evaluation of options for US siting of such a machine, with a goal of being ready to build major test facilities and demonstrator facilities within the next 10 years.

# P5 Report and Accelerator R&D Priorities

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Section 6.4.1 Particle Physics Accelerator Roadmap:

Wakefield concepts for a collider are in the early stage of development. A critical next step is the delivery of an **end-to-end design concept**, including cost scales, with self-consistent parameters throughout. This will provide an important yardstick against which to measure progress along this emerging technology path.

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accelerator designs that chart a realistic path to a **10 TeV pCM collider**.

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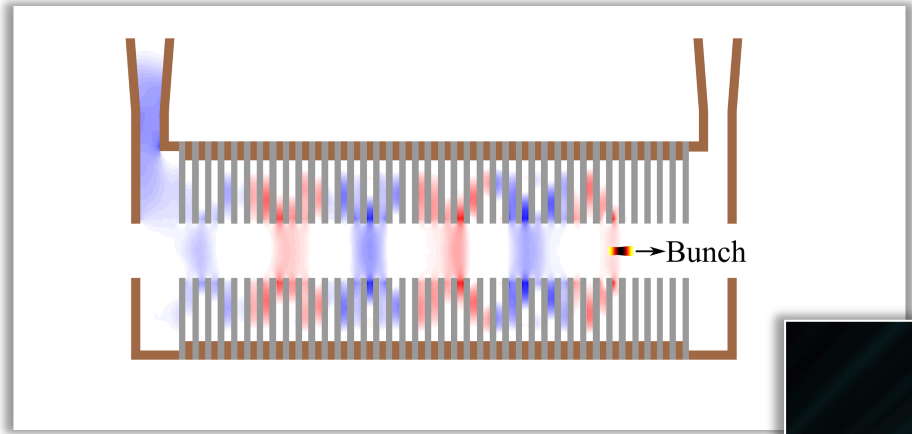
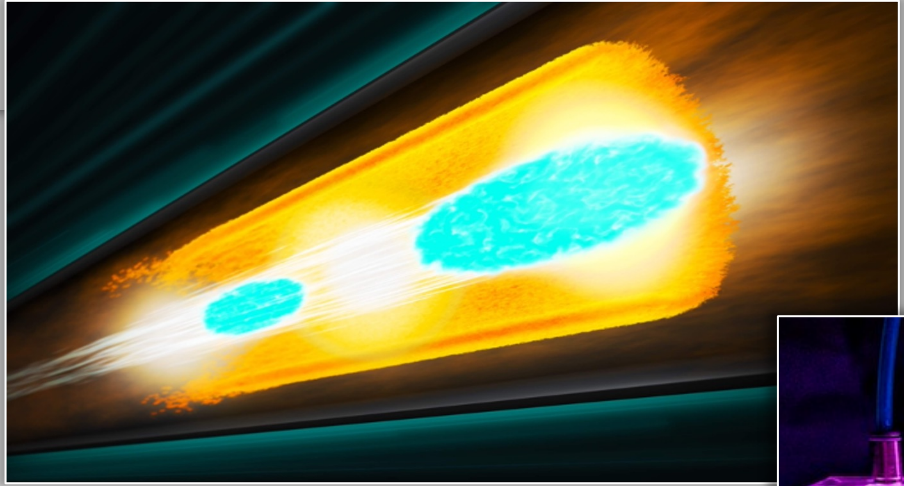
The U.S. Advanced Accelerator community, in partnership with colleagues around the world, will pursue an end-to-end design study for a 10 TeV pCM collider using beam-driven plasma, laser-driven plasma, and structure-based accelerator technology.

# Wakefield Accelerator Technologies

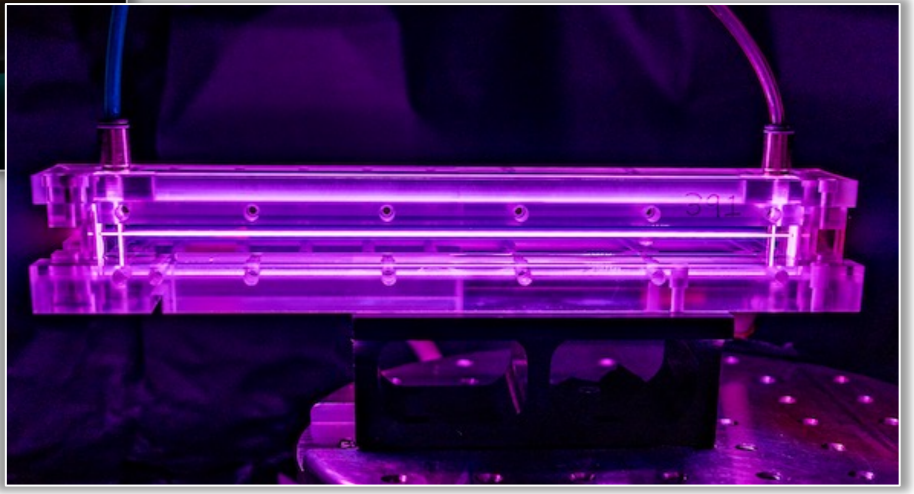
Structure Wakefield Accelerators @



Beam Driven Plasma @ SLAC

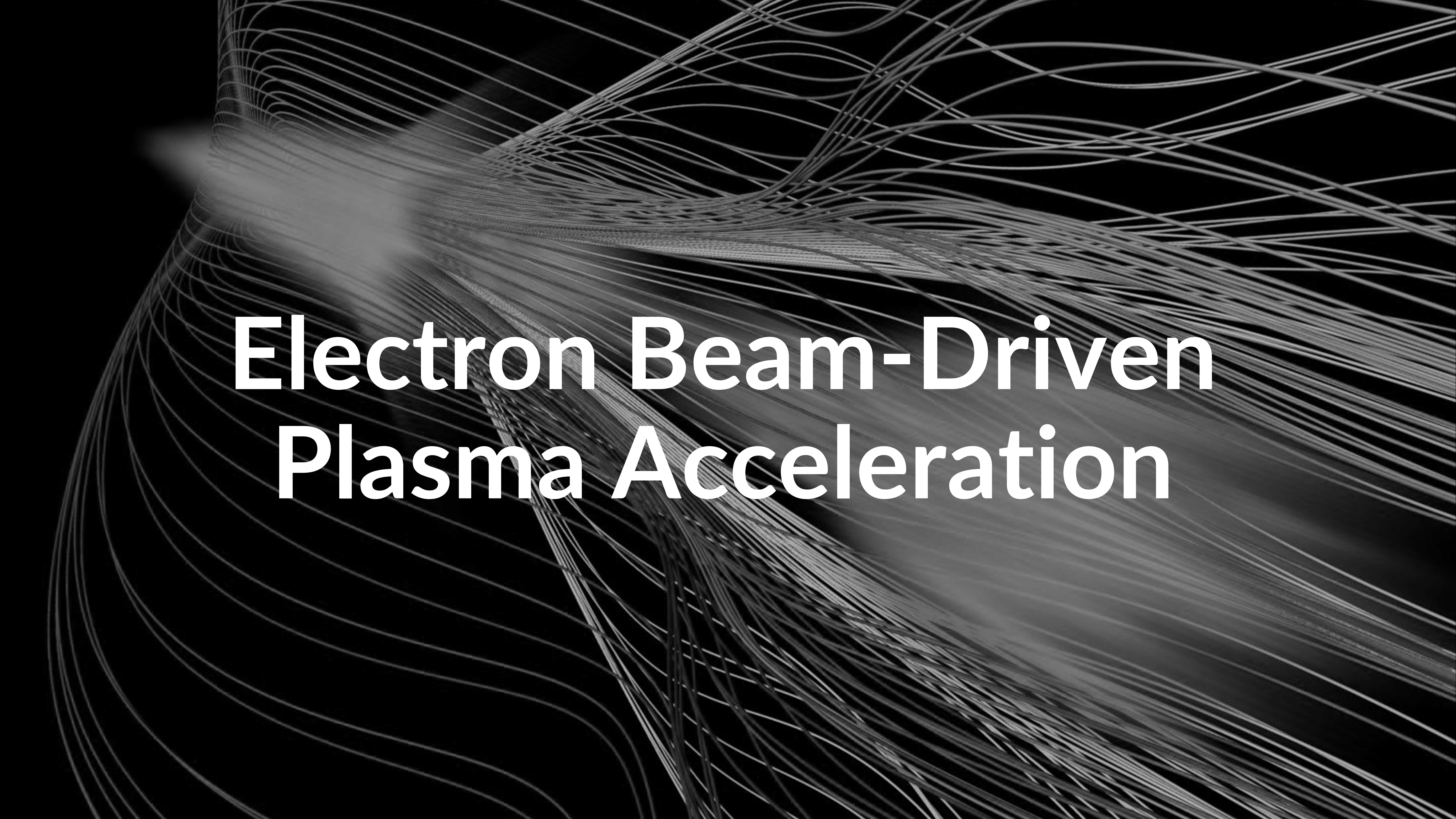


Laser Driven Plasma @ BERKELEY LAB

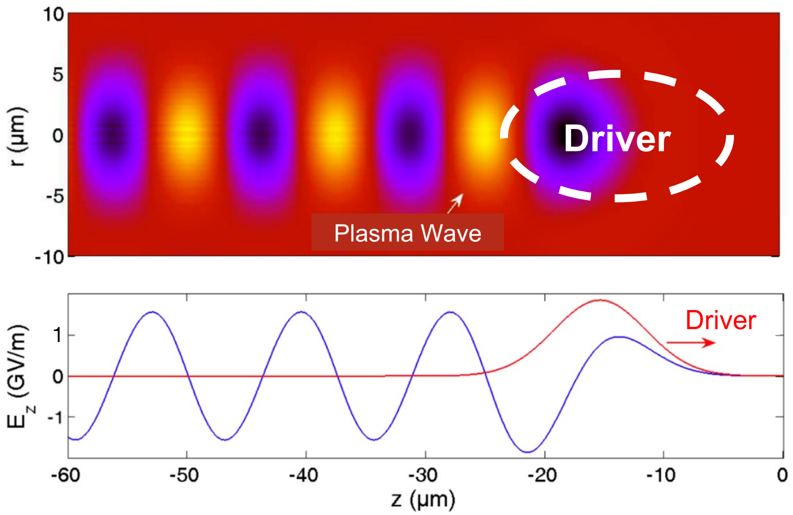


Wakefield Accelerators provide accelerating gradients greater than 1 GeV/m to enable compact, high-energy colliders.

# Electron Beam-Driven Plasma Acceleration



# Plasma Acceleration



$$\omega_p = \sqrt{\frac{n_0 e^2}{\epsilon_0 m}} \qquad E_0 = \frac{m c \omega_p}{e}$$

$$E_0 \approx 0.96 \sqrt{n(10^{14}\ \mathrm{cm}^{-3})}[\mathrm{GV/m}]$$

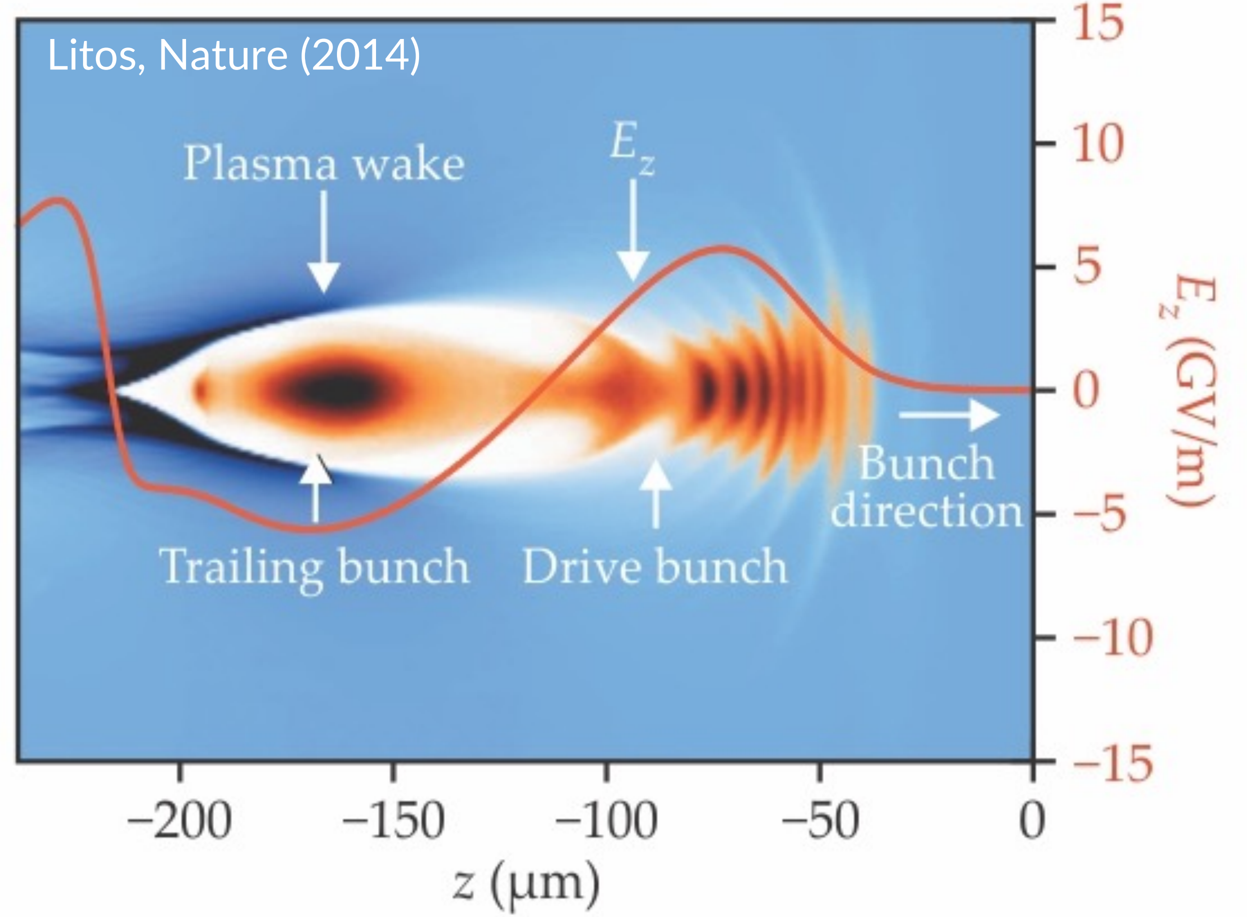
$$n_{air} = 2.69 \times 10^{19}\ \mathrm{cm}^{-3} \Rightarrow E_0 \approx 500\ \mathrm{GV/m}$$

At atmospheric pressure, plasmas provide 0.5 TeV/m accelerating gradients.

# Control of Plasma Acceleration

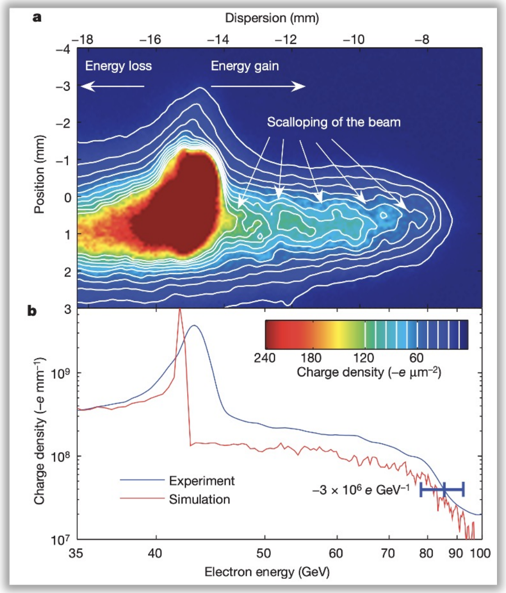
We achieve higher gradients by going to higher frequencies.

This implies control of particle beams at the sub-micron/sub-femtosecond scale.

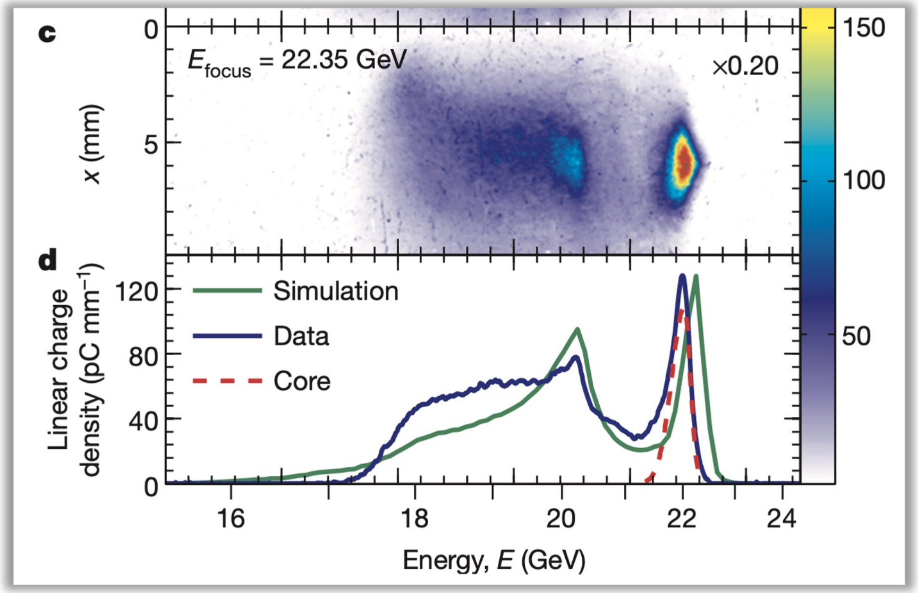

Litos, Nature (2014)

# Progress in controlling plasma acceleration

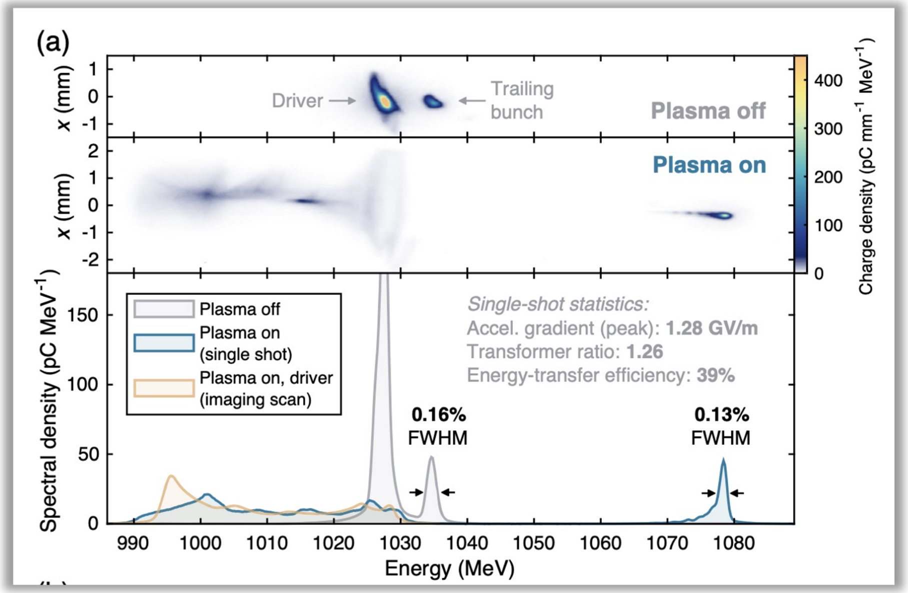
Blumenfeld, Nature (2007)



Litos, Nature (2014)



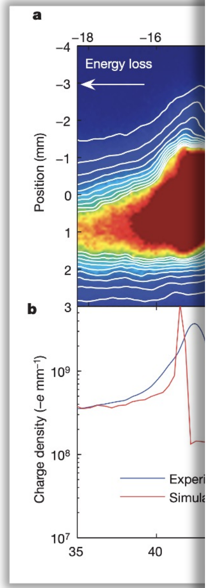
Lindstrom, PRL (2021)

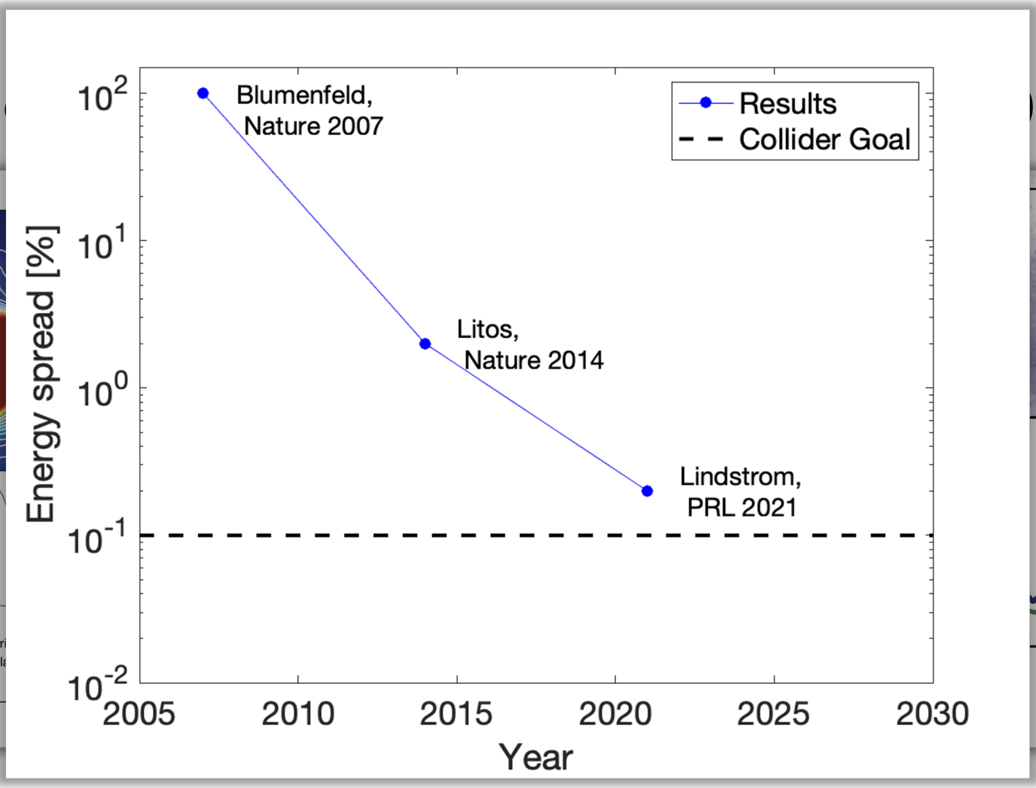


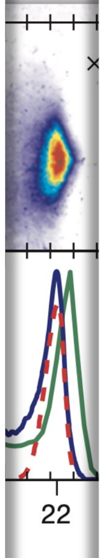
**Beam Test Facilities are evolving to deliver the required control and precision for *high-quality* acceleration.**

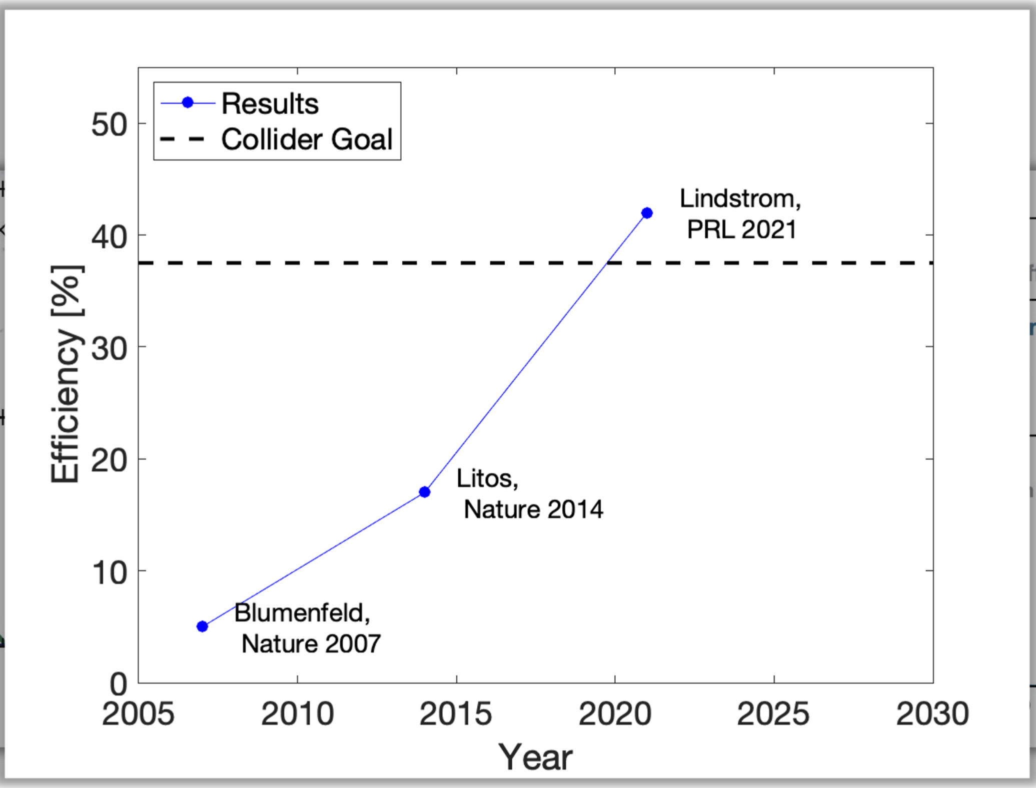
# Progress in controlling plasma acceleration

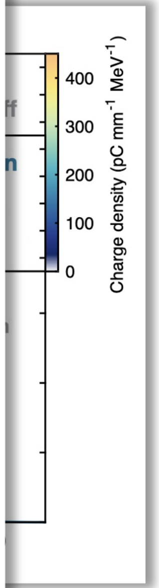
Blumenfel











**Beam Test Facilities are evolving to deliver the required control and precision for *high-quality* acceleration.**

# Collider Design

# History of Advanced Accelerator Collider Concepts

## Beam-Driven Plasma

Rosenzweig, Snowmass 1996

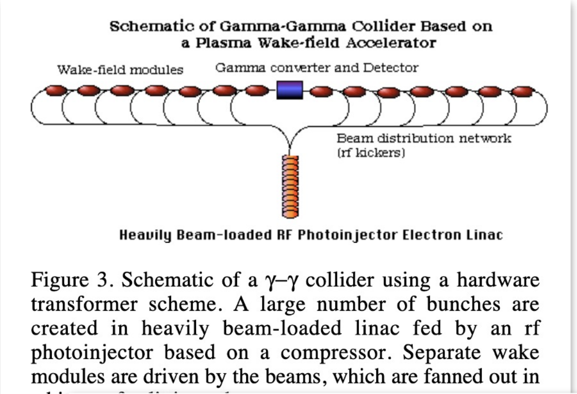
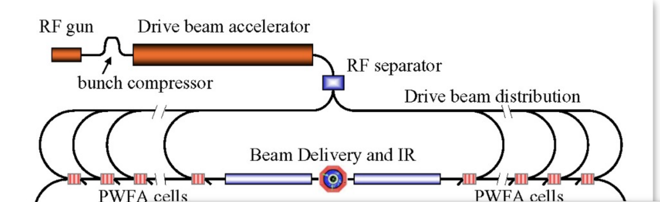


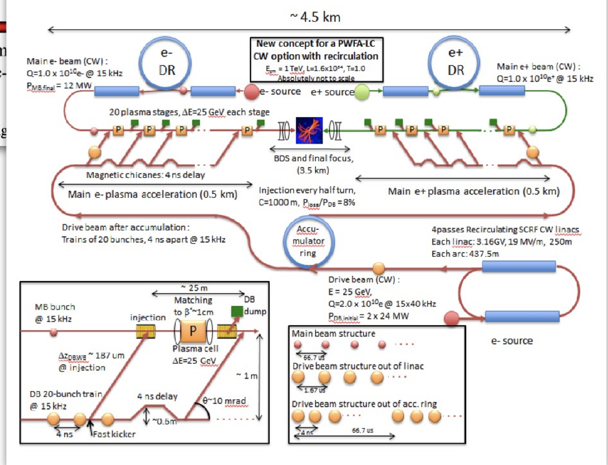
Figure 3. Schematic of a γ–γ collider using a hardware transformer scheme. A large number of bunches are created in heavily beam-loaded linac fed by an rf photoinjector based on a compressor. Separate wake modules are driven by the beams, which are fanned out in a bi

Seryi, PAC09 2009



Adli, Snowmass 2013

**Figure 1: Layout of a 1 TeV PWFA Linear Collider**



## Structure-Based Acceleration

Gai, AAC 1998

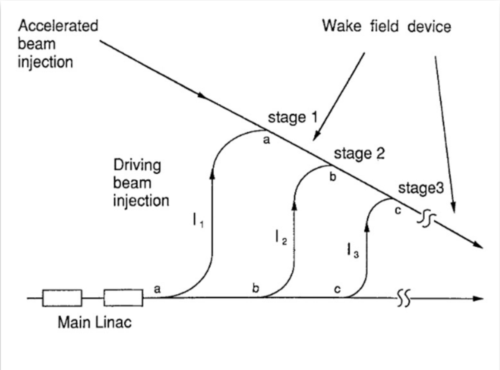
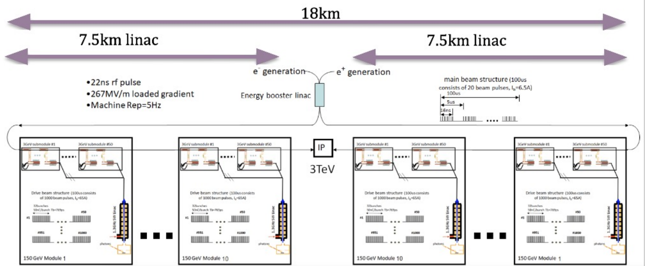


Figure 1. Schematic design of multi-stage wake field accelerator.

Jing, IPAC 2013

**ARGONNE FLEXIBLE LINEAR COLLIDER**

**3TeV 30MW beam power TBA**



Jing, JINST 2022

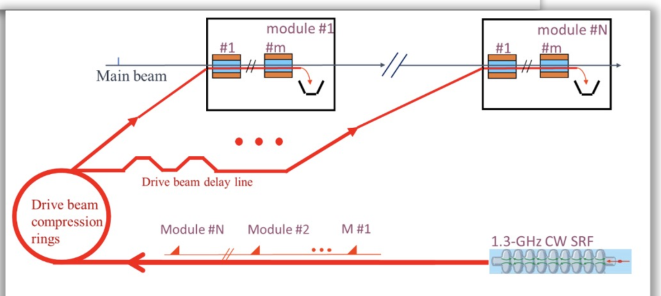
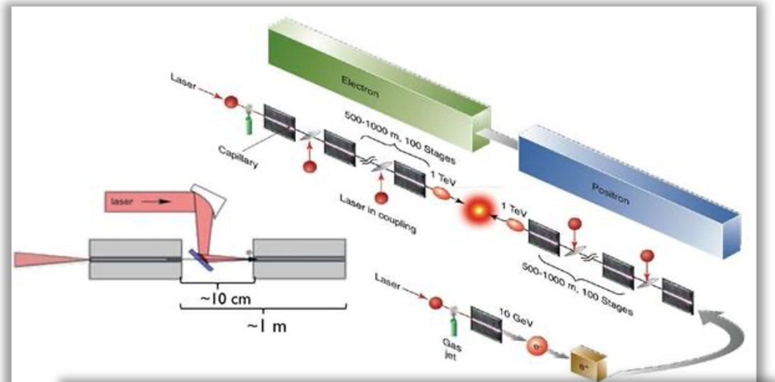


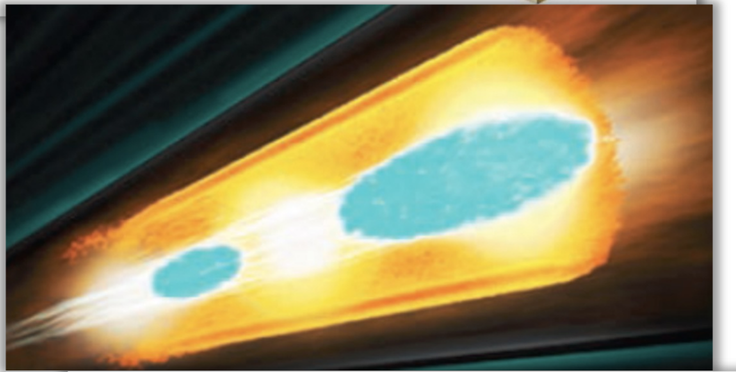
**Figure 3.** Block diagram of a 100-GeV CWA concept.

## Laser-Driven Plasma

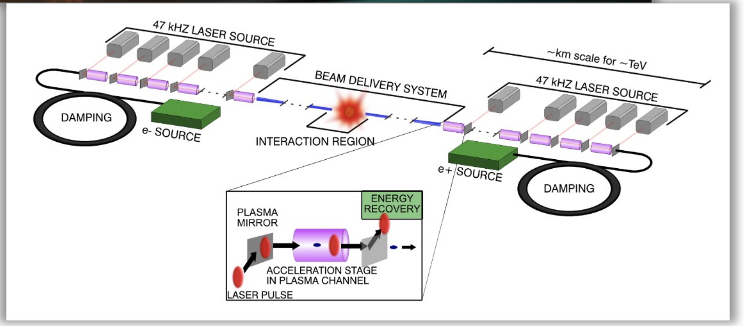
Leamans, Phys. Today 2023



Schroeder, NIM A 2016



Schroeder, JINST 2023



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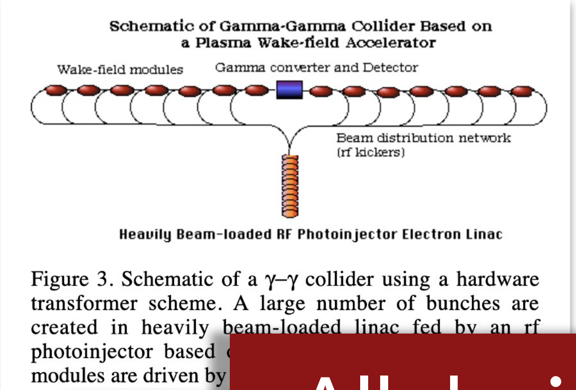

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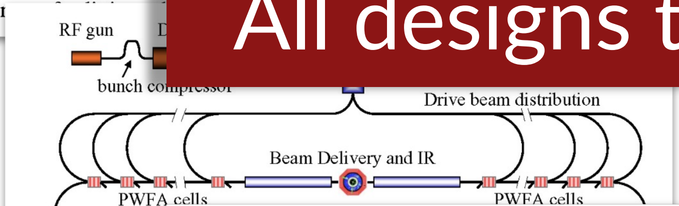

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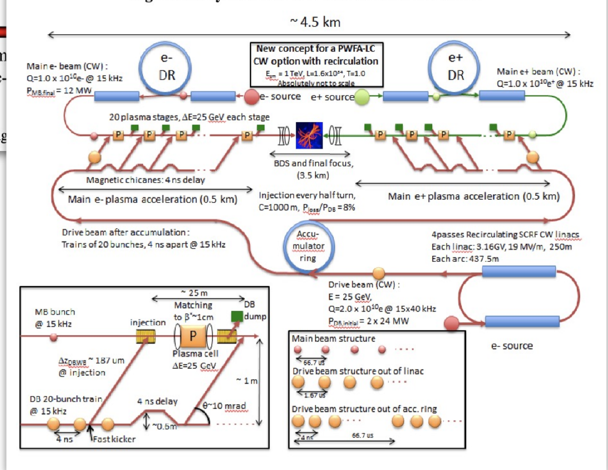

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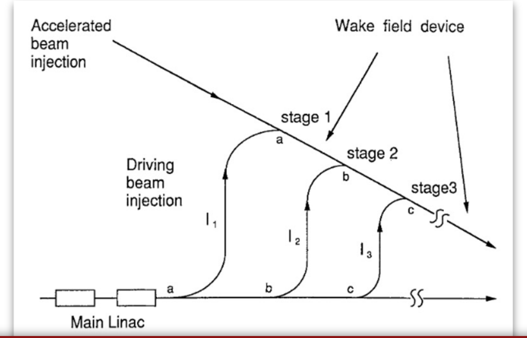
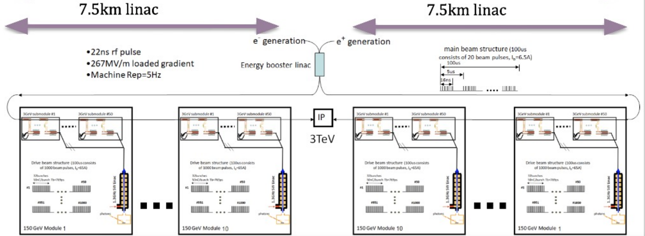


Jing, IPAC 2013



Jing, JINST 2022

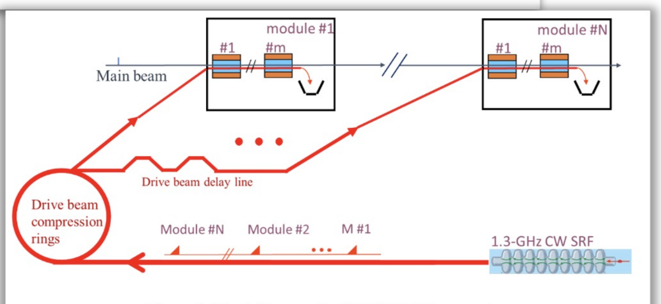
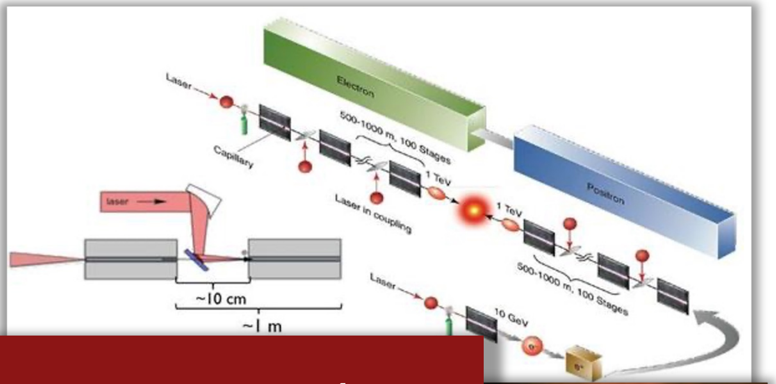


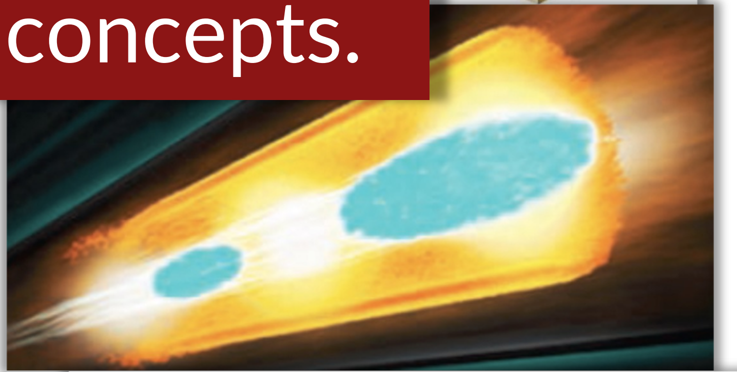
Figure 3. Block diagram of a 100-GeV CWA concept.

## Laser-Driven Plasma

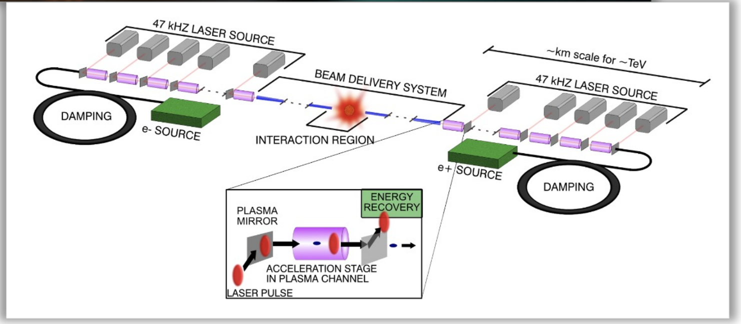
mans, Phys. Today 2023



Schroeder, NIM A



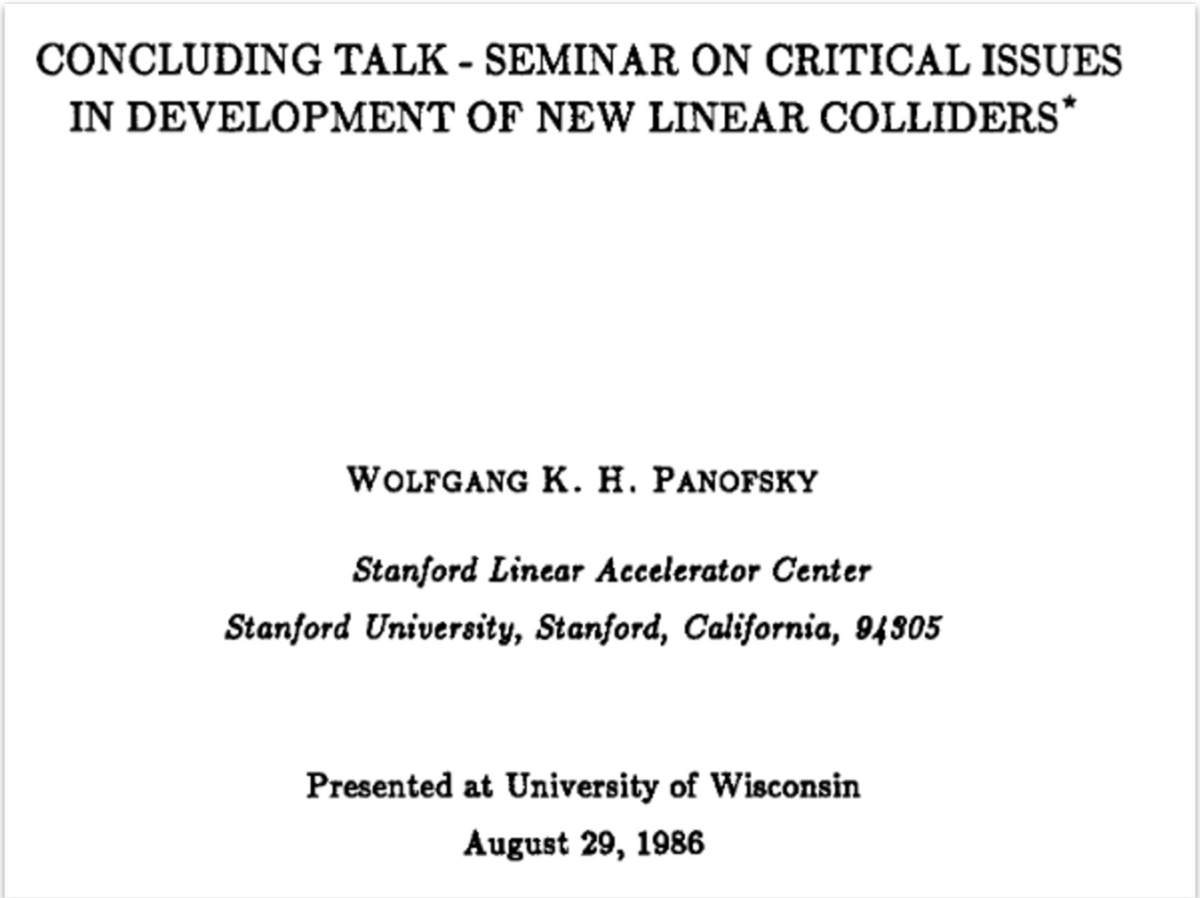
Schroeder, JINST 2023



**All designs thus far are straw-person concepts.**

# What goes into collider design?

Symposium on Advanced Accelerator Concepts, Madison, WI, 1986

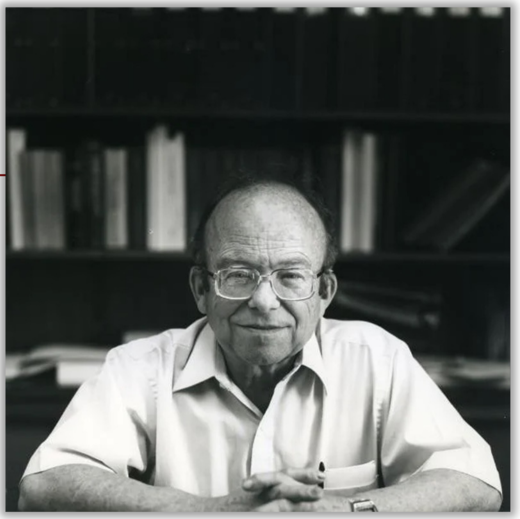


## CONCLUDING TALK - SEMINAR ON CRITICAL ISSUES IN DEVELOPMENT OF NEW LINEAR COLLIDERS*

WOLFGANG K. H. PANOFSKY

*Stanford Linear Accelerator Center*
*Stanford University, Stanford, California, 94305*

Presented at University of Wisconsin
August 29, 1986



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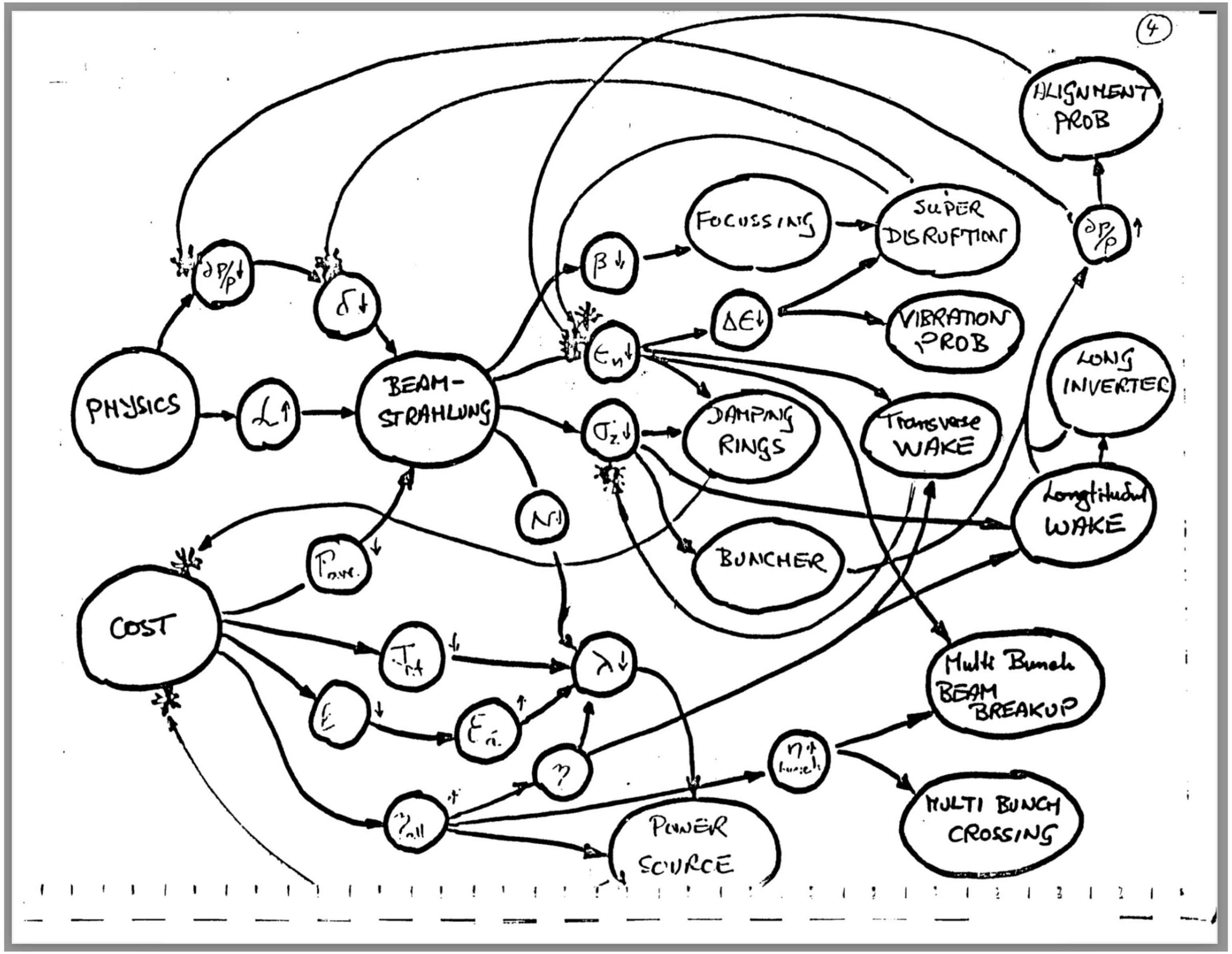
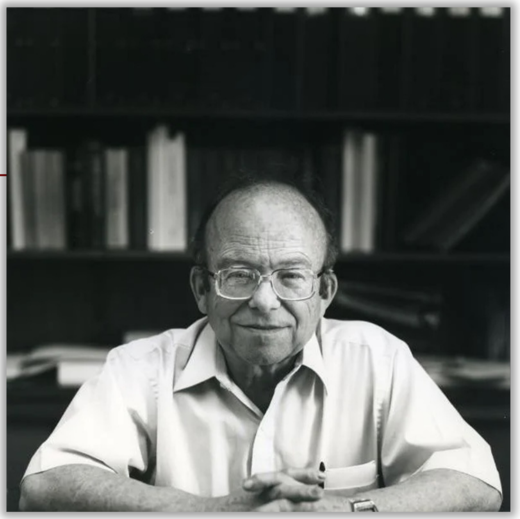




# Charge from P5 Report

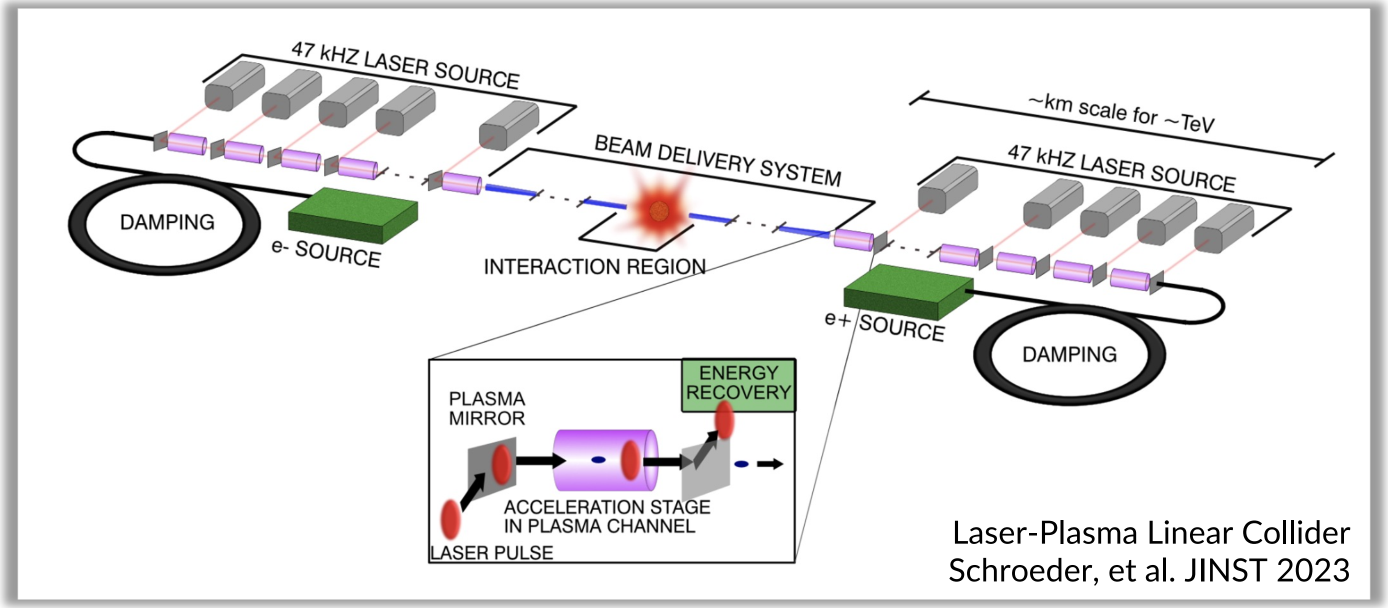
Section 6.4.1 Particle Physics Accelerator Roadmap:

Wakefield concepts for a collider are in the early stage of development. A critical next step is the delivery of an **end-to-end design concept**, including cost scales, with self-consistent parameters throughout. This will provide an important yardstick against which to measure progress along this emerging technology path.

The Design of a **10 TeV** parton-center-of-mass (pCM) collider based on **wakefield accelerator (WFA) technology** is a **global** undertaking.

We are in the early stages of developing a collaboration with our European colleagues. We plan to partner with ALEGRO and HALHF in this effort.

# What is an End-to-End Design Study?



Laser-Plasma Linear Collider
Schroeder, et al. JINST 2023

**Challenges**

Stability Energy Recovery Repetition Rate Efficiency

Geometric gradient Positron Acceleration Staging Beam Delivery Systems Jitter budget

**How do these components fit together?**

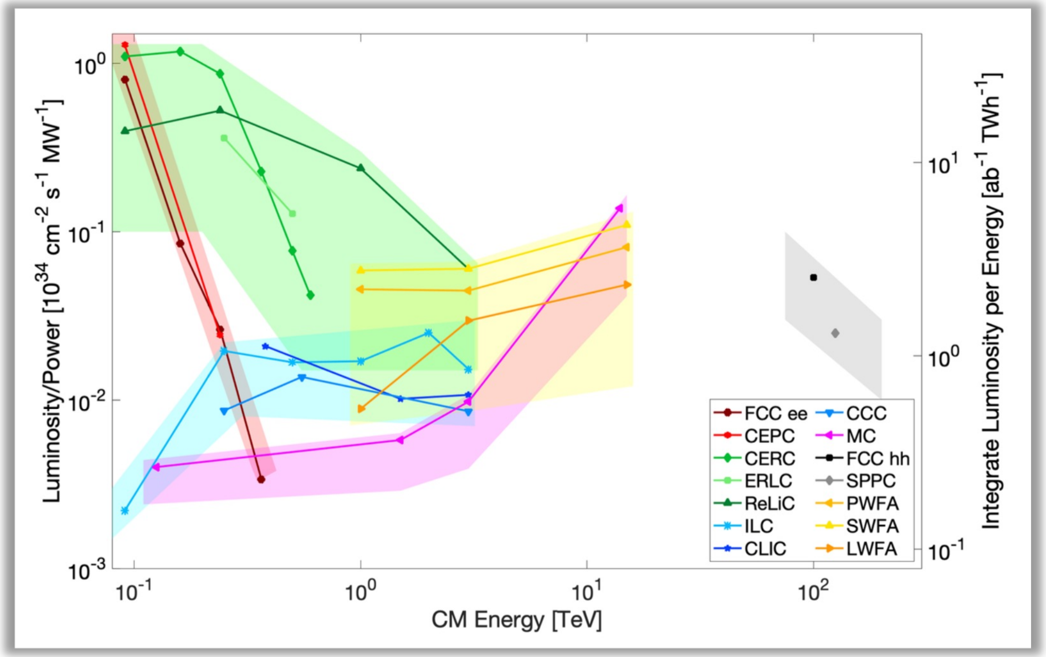
# Environmental Impact and Power Consumption

The carbon impact of colliders comes from:

- Construction – smaller colliders are better!
- Operation

Maximizing luminosity-per-power minimizes carbon footprint.

ITF Report, JINST (2023)



The key metric is “luminosity-per-beam-power”.

# Environmental Impact: A “new” constraint

For a given luminosity and energy target, we can place strong constraints on collider designs.

Geometric Luminosity

$$\mathcal{L} = \frac{fN^2}{4\pi\sigma_x\sigma_y}$$

Figure of Merit:
Luminosity per beam power

$$\frac{\mathcal{L}}{P_{tot}} = \frac{\eta N}{4\pi\sigma_x\sigma_y E_b}$$

10 TeV collider: $E_b$ = 5 TeV and $\mathcal{L} = 10^{35}$ cm$^{-2}$ s$^{-1}$

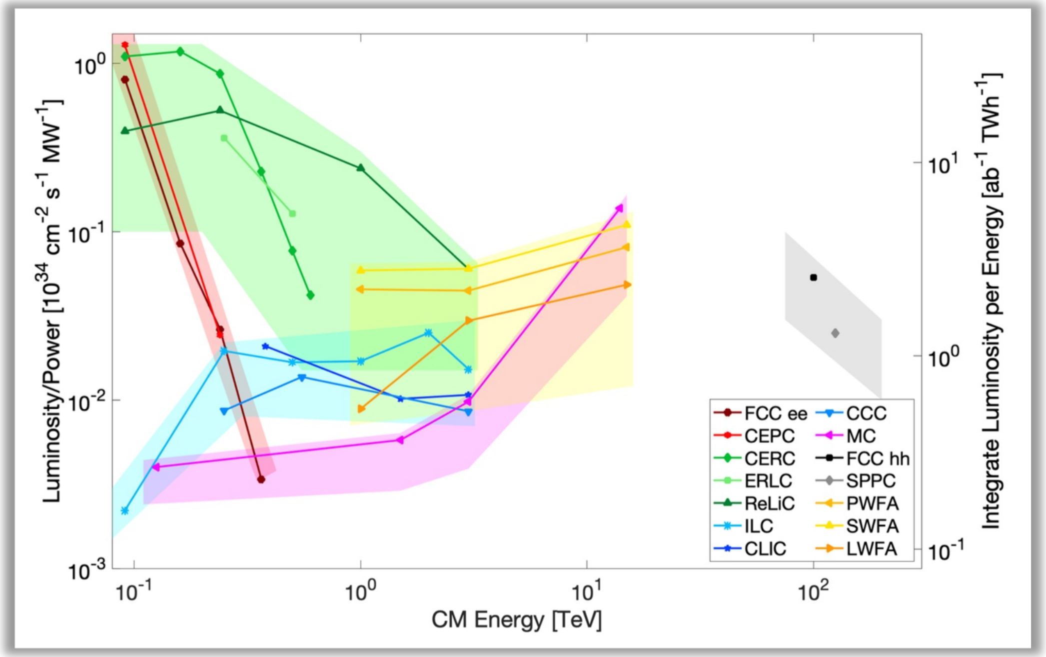
$$P_{tot} = \underbrace{\mathcal{L}E_b}_{\text{Fixed}}\frac{4\pi\sqrt{\beta_x\varepsilon_x}\sqrt{\beta_y\varepsilon_y}}{\eta N}$$

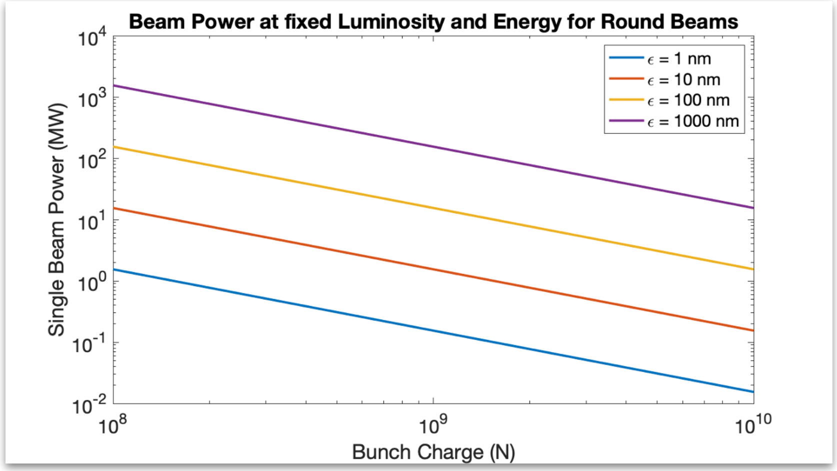
Minimize

Maximize

**For a fixed luminosity and collision energy, higher bunch charges are favored.**

ITF Report, JINST (2023)





# But wait! Beamstrahlung . . .

Beamstrahlung (radiation during collisions) reduces the energy of the colliding particles. This is a significant effect at 10 TeV.

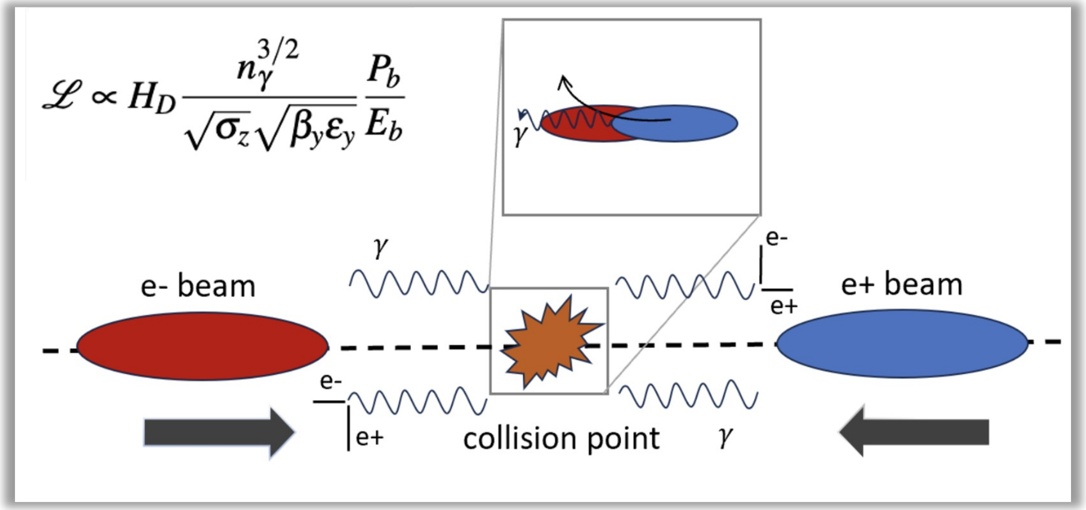
Traditional linear colliders desire low beamstrahlung:

- High-charge bunches not necessarily favored.
- Flat beams are favored.

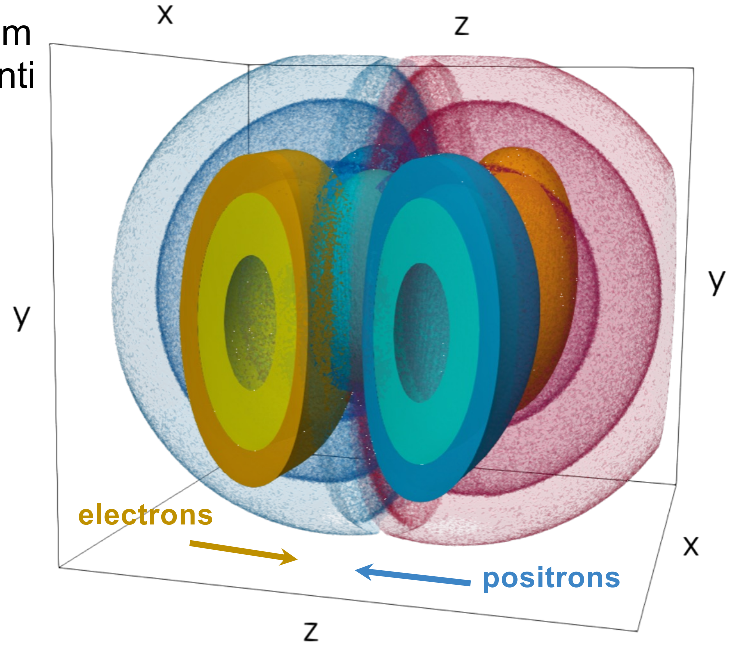
At 10 TeV, large beamstrahlung may be inevitable. We will consider:

- $e^+e^-$, $e^-e^-$, $\gamma\gamma$ collisions
- Round beam collisions in addition to flat beam collisions.

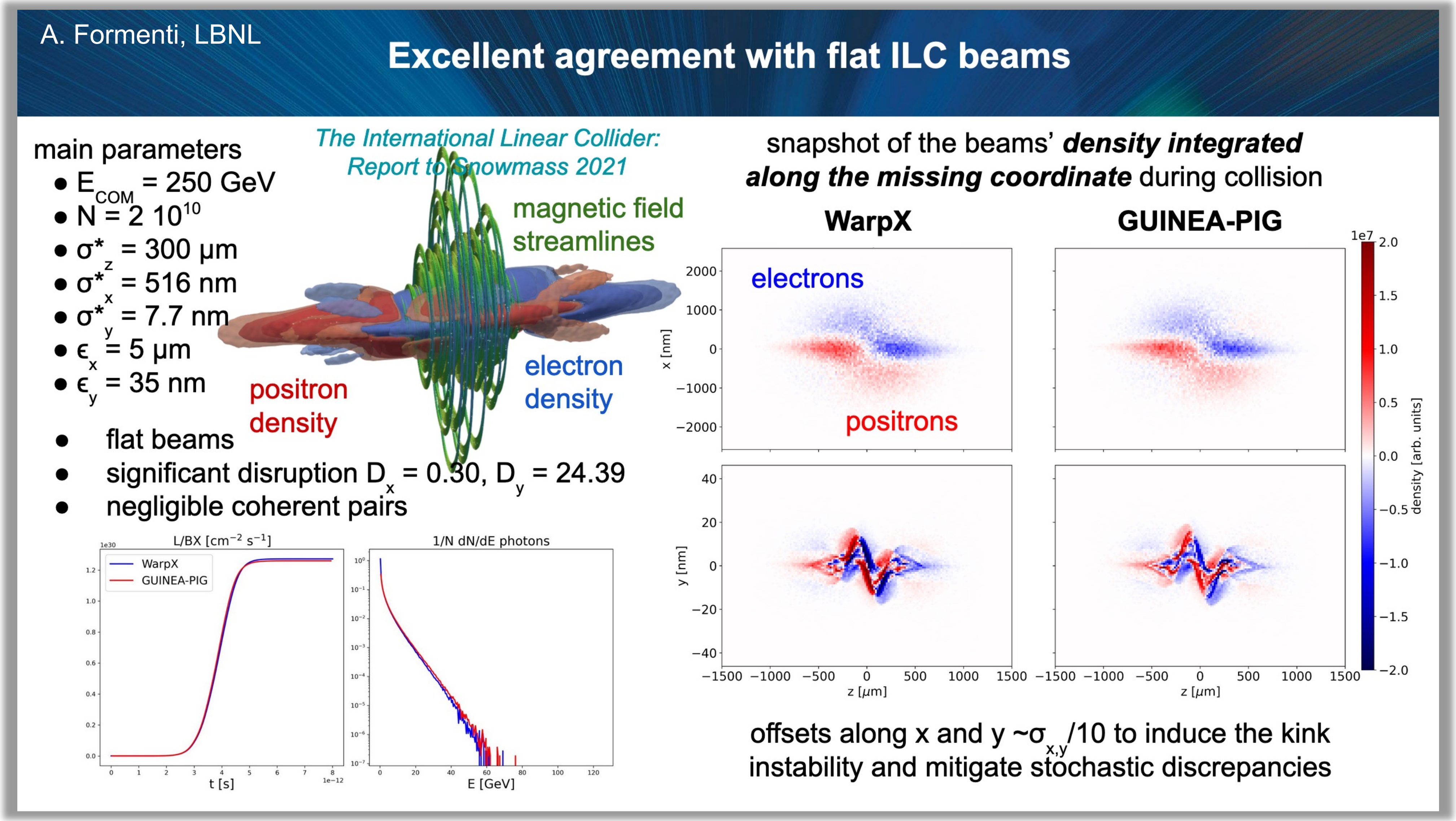
**Collider designs must examine trade-offs at every stage of the process.**



WarpX Sim
A. Formenti
LBNL



# Development of HPC PIC Codes for Beam-Beam



A. Formenti, LBNL

## Excellent agreement with flat ILC beams

main parameters

- $E_{COM}$ = 250 GeV
- N = 2 $10^{10}$
- $\sigma^*_z$ = 300 µm
- $\sigma^*_x$ = 516 nm
- $\sigma^*_y$ = 7.7 nm
- $\epsilon_x$ = 5 µm
- $\epsilon_y$ = 35 nm

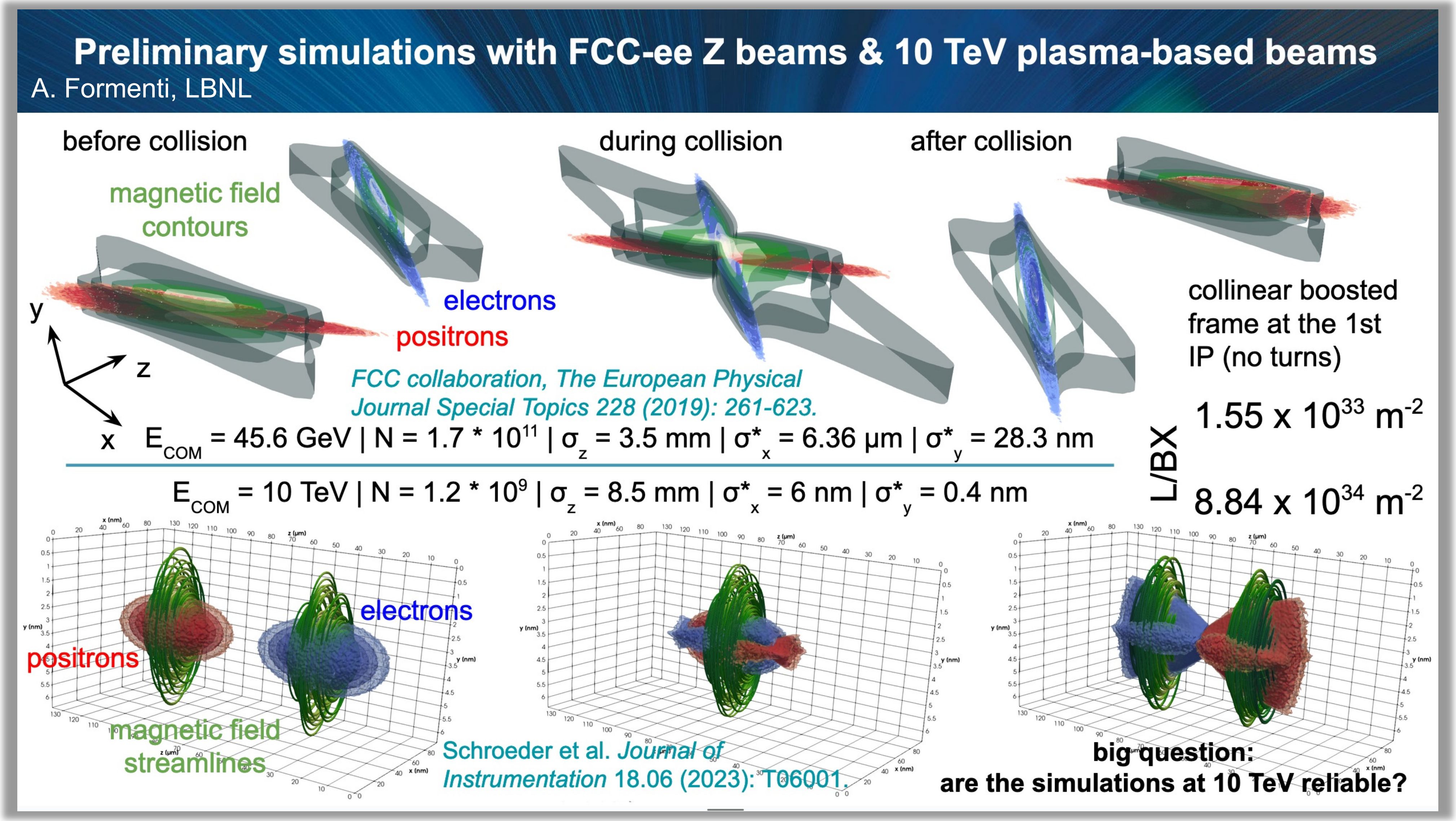
- flat beams
- significant disruption $D_x$ = 0.30, $D_y$ = 24.39
- negligible coherent pairs

*The International Linear Collider: Report to Snowmass 2021*

snapshot of the beams' ***density integrated along the missing coordinate*** during collision

offsets along x and y ~$\sigma_{x,y}$/10 to induce the kink instability and mitigate stochastic discrepancies

# Development of HPC PIC Codes for Beam-Beam



## Preliminary simulations with FCC-ee Z beams & 10 TeV plasma-based beams

A. Formenti, LBNL

before collision

during collision

after collision

magnetic field contours

electrons

positrons

y

z

x

FCC collaboration, *The European Physical Journal Special Topics 228 (2019): 261-623.*

$E_{COM}$ = 45.6 GeV | N = 1.7 * $10^{11}$ | $\sigma_z$ = 3.5 mm | $\sigma^*_x$ = 6.36 μm | $\sigma^*_y$ = 28.3 nm

$E_{COM}$ = 10 TeV | N = 1.2 * $10^{9}$ | $\sigma_z$ = 8.5 mm | $\sigma^*_x$ = 6 nm | $\sigma^*_y$ = 0.4 nm

collinear boosted frame at the 1st IP (no turns)

L/BX

1.55 x $10^{33}$ $m^{-2}$

8.84 x $10^{34}$ $m^{-2}$

electrons

positrons

magnetic field streamlines

Schroeder et al. *Journal of Instrumentation* 18.06 (2023): T06001.

**big question:**

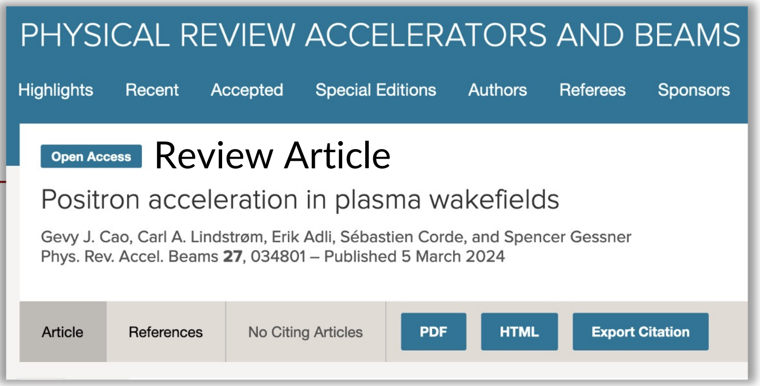
**are the simulations at 10 TeV reliable?**

# Positron Acceleration in Plasma

A major outstanding challenge is positron acceleration in plasma.

Plasmas are *asymmetric* accelerators.

Our review article compares different concepts of positron acceleration in the context of a collider.

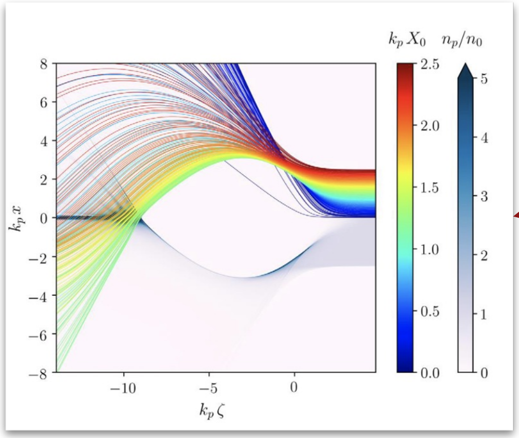

PHYSICAL REVIEW ACCELERATORS AND BEAMS

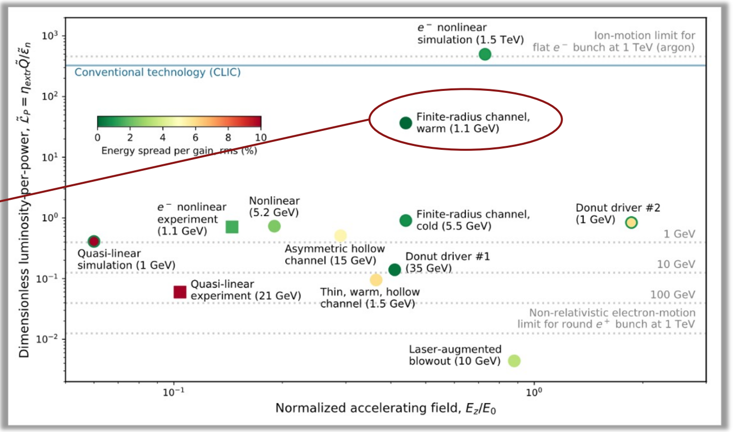
Review Article

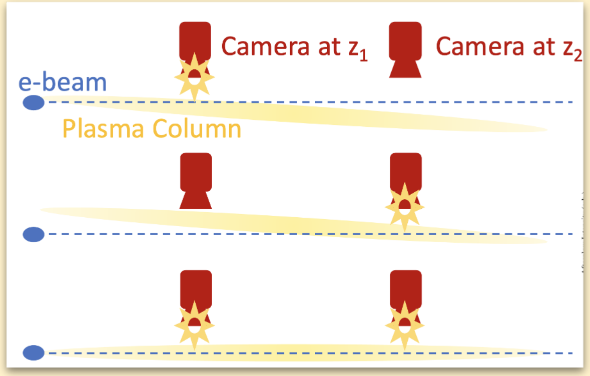
Positron acceleration in plasma wakefields

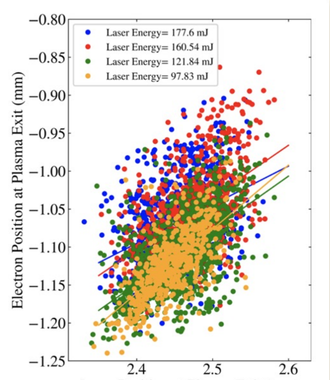
Gevy J. Cao, Carl A. Lindstrøm, Erik Adli, Sébastien Corde, and Spencer Gessner
Phys. Rev. Accel. Beams **27**, 034801 – Published 5 March 2024

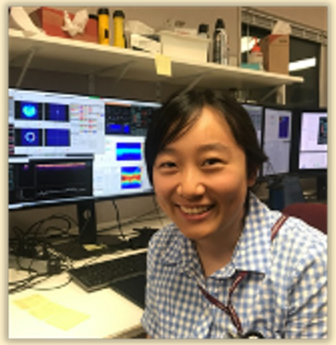
S. Diederichs, et al, "High-quality positron acceleration in beam-driven plasma accelerators," PRAB, 2020.










CU Boulder Ph.D. Student Valentina Lee

We are pursuing the finite-radius regime in experiments at FACET-II.

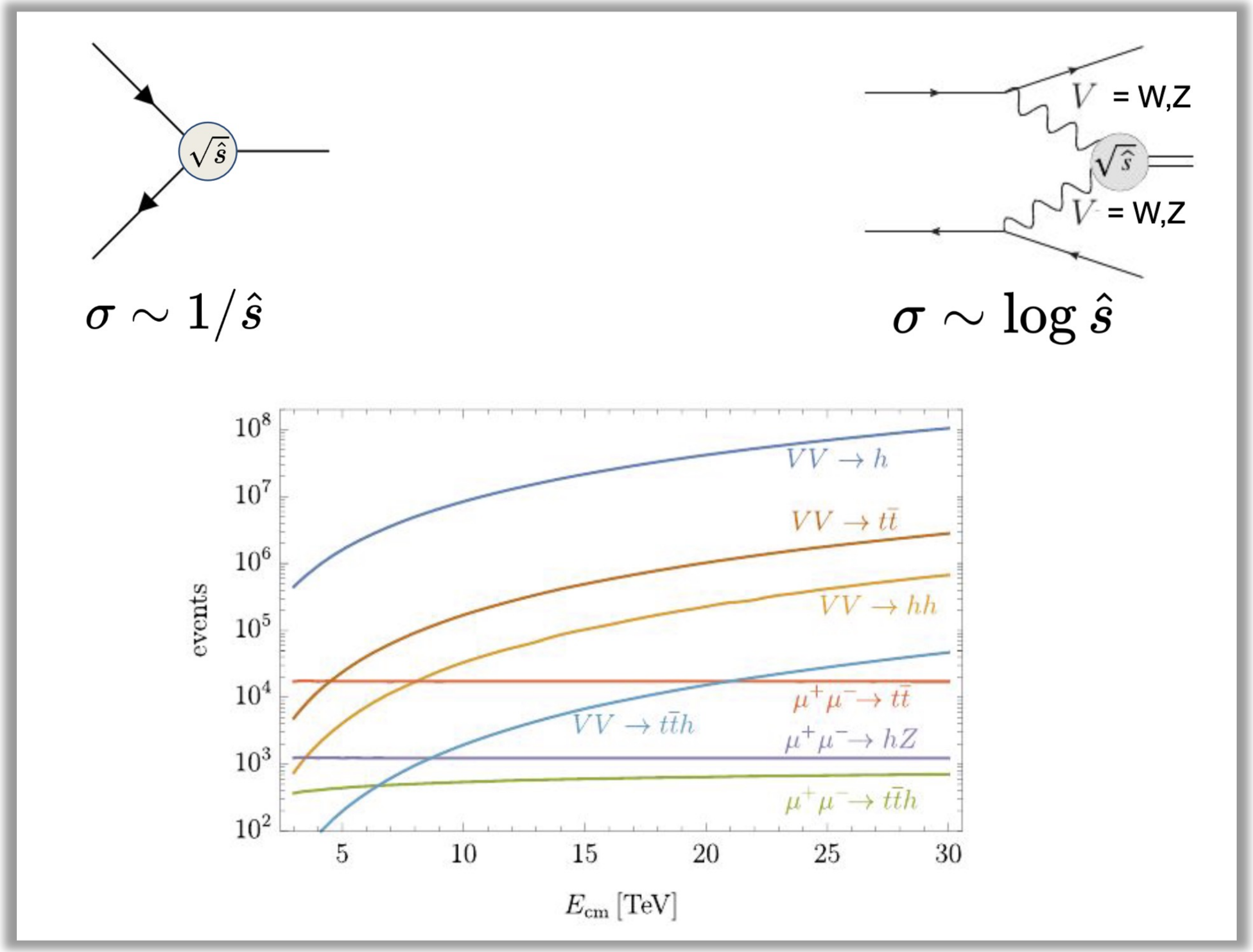
E333 Experiment at FACET-II, PI S. Gessner: Demonstration of finite-radius regime.

# 10 TeV: A new paradigm

At 10 TeV, there is a very high cross section for Vector Boson Fusion (VBF).

Most of the luminosity comes from the VBF process, rather than s-channel annihilation traditional associated with electron-positron linear colliders.

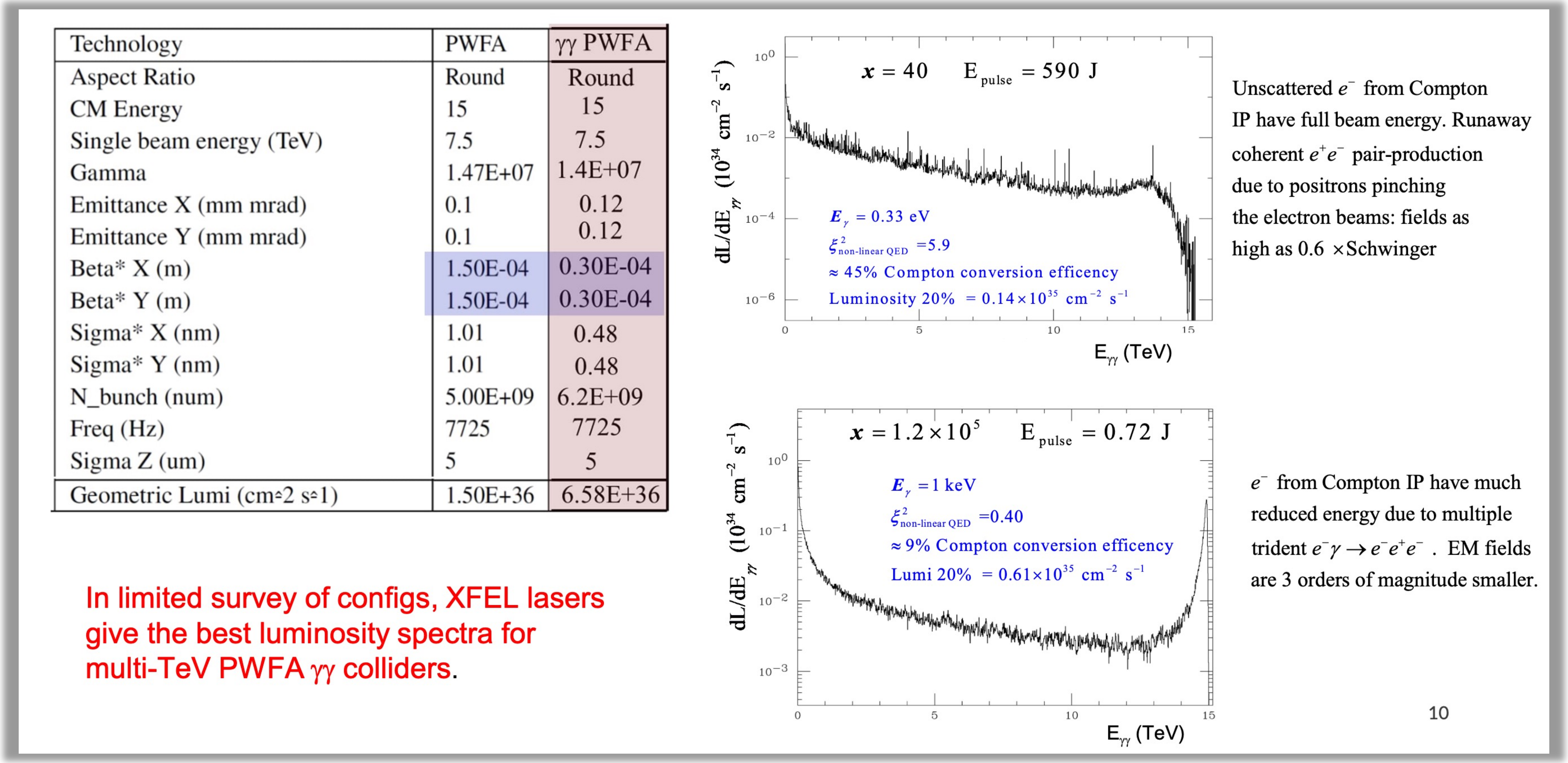
VBF provides the largest production channels for high-energy $e^+e^-$, $e^-e^-$, $\gamma\gamma$, and $\mu^+\mu^-$ colliders.



**A 10 TeV linear collider does not have to be an electron-positron collider.**

Simone Pagan Griso, LBNL and
Muon Collide Forum Report
arXiv:2209.01318

# $\gamma\gamma$ Collisions



| Technology | PWFA | $\gamma\gamma$ PWFA |
|---|---|---|
| Aspect Ratio | Round | Round |
| CM Energy | 15 | 15 |
| Single beam energy (TeV) | 7.5 | 7.5 |
| Gamma | 1.47E+07 | 1.4E+07 |
| Emittance X (mm mrad) | 0.1 | 0.12 |
| Emittance Y (mm mrad) | 0.1 | 0.12 |
| Beta* X (m) | 1.50E-04 | 0.30E-04 |
| Beta* Y (m) | 1.50E-04 | 0.30E-04 |
| Sigma* X (nm) | 1.01 | 0.48 |
| Sigma* Y (nm) | 1.01 | 0.48 |
| N_bunch (num) | 5.00E+09 | 6.2E+09 |
| Freq (Hz) | 7725 | 7725 |
| Sigma Z (um) | 5 | 5 |
| Geometric Lumi (cm-2 s-1) | 1.50E+36 | 6.58E+36 |

In limited survey of configs, XFEL lasers give the best luminosity spectra for multi-TeV PWFA $\gamma\gamma$ colliders.

Unscattered $e^-$ from Compton IP have full beam energy. Runaway coherent $e^+e^-$ pair-production due to positrons pinching the electron beams: fields as high as 0.6 ×Schwinger

$e^-$ from Compton IP have much reduced energy due to multiple trident $e^-\gamma \rightarrow e^-e^+e^-$ . EM fields are 3 orders of magnitude smaller.

Tim Barklow, SLAC

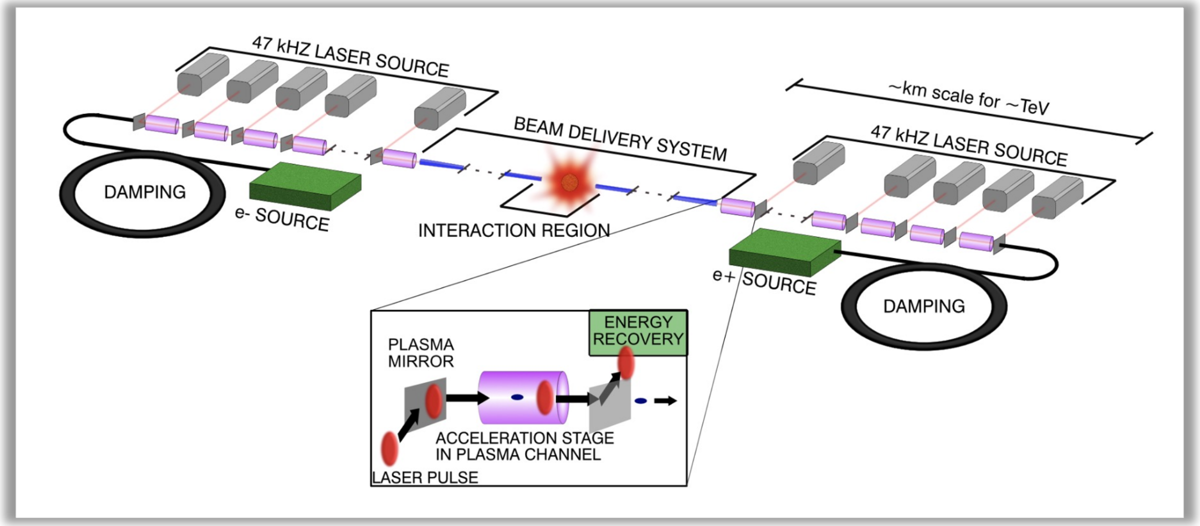
# Working Groups

Working groups are connected to collider components:

- Sources (incl. damping rings)

  Drivers
  - Laser
  - Beams - SWFA
  - Beams - PWFA

  Linacs (including staging)
  - LWFA
  - SWFA
  - PWFA
- Beam delivery system
- Beam-beam interactions
- Beam diagnostics
- Machine-detector interface
- HEP detector
- HEP physics case
- Environmental impact



Green = Advanced acc. technology independent

Orange/blue/purple = technology specific

Red = HEP and broader community

# Example: Particle Sources Working group

## Technology metrics:

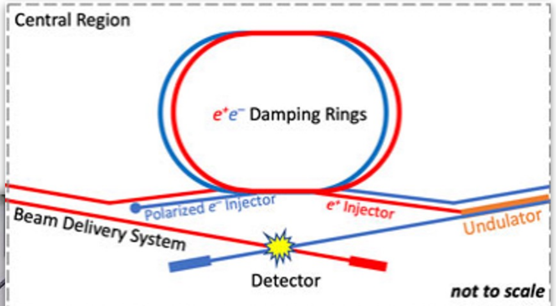
- Bunch charge
- Emittance
- Brightness
- Stability
- Experimental demonstrations

The development of metrics by each working group will inform the global design metrics for the colliders.

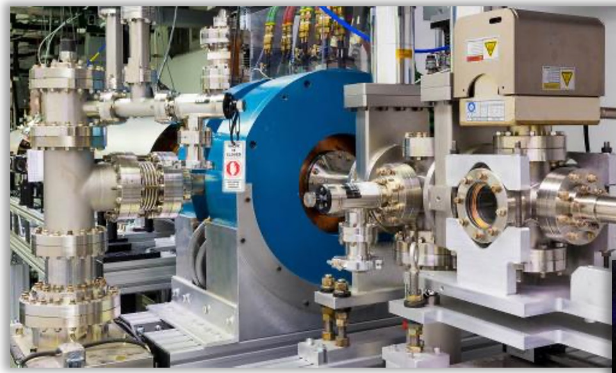
The global design metrics will then inform working group decisions.

## Possible Technologies:

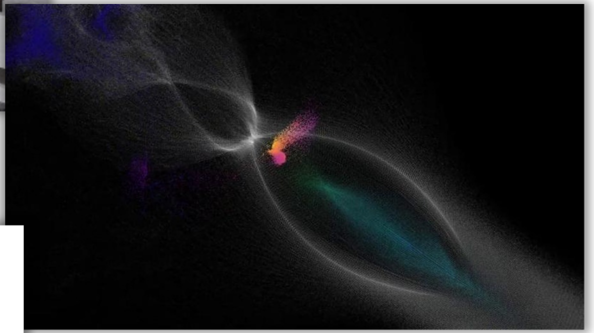
Damping rings



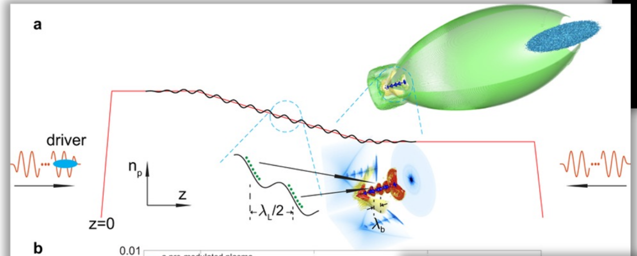
RF Photocathode



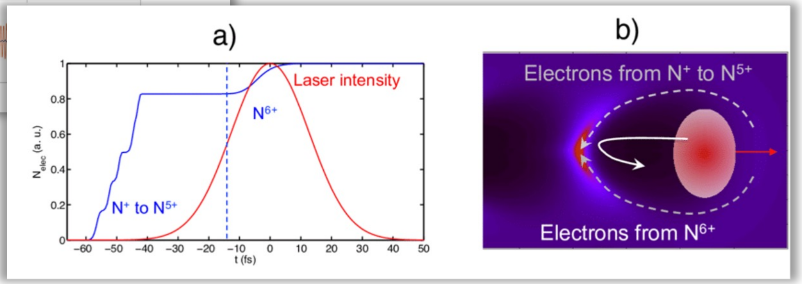
Trojan Horse



Downramp Injection



Ionization Injection



# Tentative Study Timeline

| Ongoing | 1 year | 2 year | 3 year | 4 year |
|---|---|---|---|---|
| Study organization. | Unified study of SWFA/PWFA/LWFA for electron arm of linac | Review tech options and converge on accelerator concepts. | Collaboration on designs and self-consistent parameters. | End-to-end design study report due sometime in 2028. |
| Solicit input from HEP physicists on $e^+e^-$, $e^-e^-$, $\gamma\gamma$ collisions. | Intensify engagement on “traditional systems” and begin work on BDS, sources, etc | Review options and converge on HEP collider type ($e^+e^-$, $e^-e^-$, $\gamma\gamma$) | Identification of required R&D and demo facilities | |
| | Provide community input for the next ESPP, March 2025 | Intensify engagement with HEP on detectors | | |

**Engagement beyond AAC**

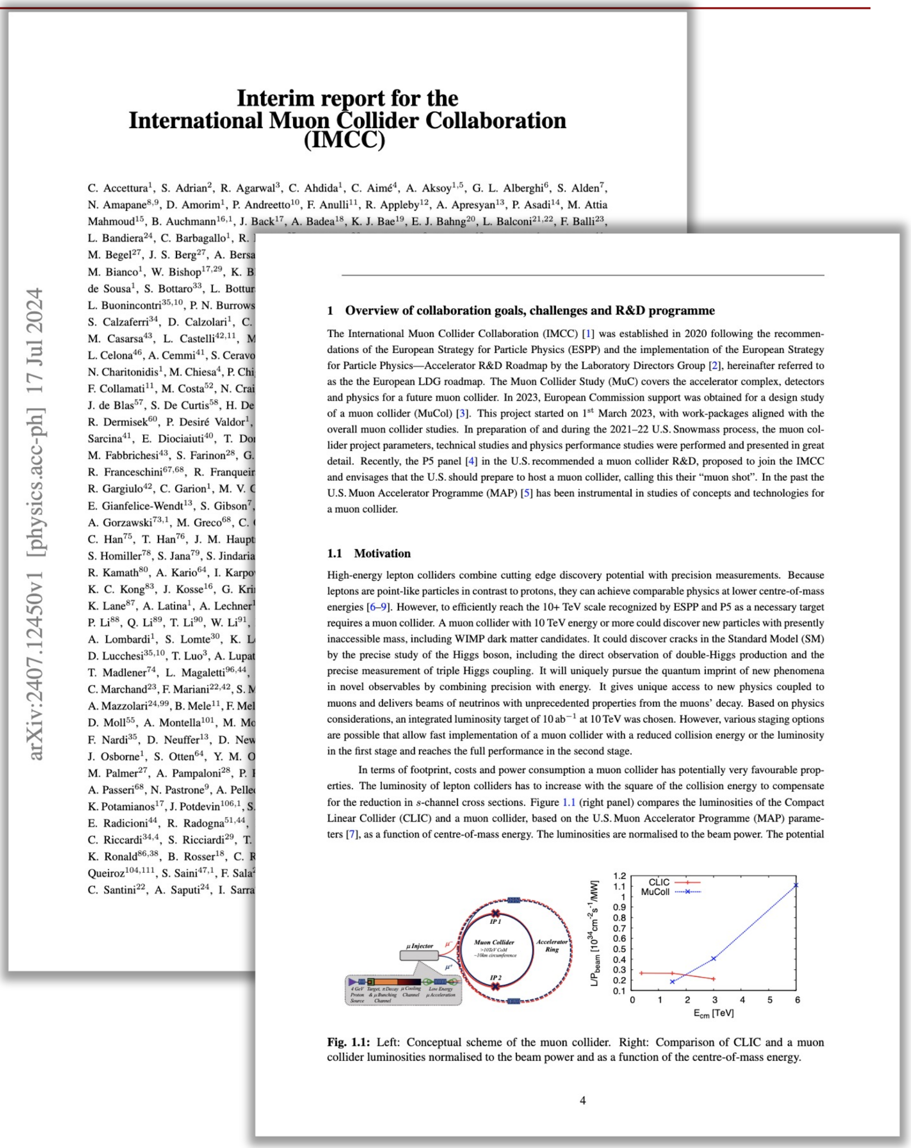
# Proposed Deliverables

Year 1:
- WG metrics and technology options.
- Global metrics determined by community.
- Input to ESPP.

Year 2:
- Interim “metric-aware” design report.

Year 3:
- R&D and facilities roadmap.
- Design report updates.

Year 4:
- End-to-end design study on 10 TeV collider.



arXiv:2407.12450v1 [physics.acc-ph] 17 Jul 2024

**Interim report for the**
**International Muon Collider Collaboration**
**(IMCC)**

C. Accettura[1], S. Adrian[2], R. Agarwal[3], C. Ahdida[1], C. Aimé[4], A. Aksoy[1,5], G. L. Alberghi[6], S. Alden[7],
N. Amapane[8,9], D. Amorim[1], P. Andreetto[10], F. Anulli[11], R. Appleby[12], A. Apresyan[13], P. Asadi[14], M. Attia
Mahmoud[15], B. Auchmann[16,1], J. Back[17], A. Badea[18], K. J. Bae[19], E. J. Bahng[20], L. Balconi[21,22], F. Balli[23],
L. Bandiera[24], C. Barbagallo[1], R.
M. Begel[27], J. S. Berg[27], A. Bersa
M. Bianco[1], W. Bishop[17,29], K. B
de Sousa[1], S. Bottaro[33], L. Bottur
L. Buonincontri[35,10], P. N. Burrows
S. Calzaferri[34], D. Calzolari[1], C.
M. Casarsa[43], L. Castelli[42,11], M
L. Celona[46], A. Cemmi[41], S. Ceravo
N. Charitonidis[1], M. Chiesa[4], P. Chi
F. Collamati[11], M. Costa[52], N. Crai
J. de Blas[57], S. De Curtis[58], H. De
R. Dermisek[60], P. Desiré Valdor[1],
Sarcina[41], E. Diociaiuti[40], T. Do
M. Fabbrichesi[43], S. Farinon[28], G.
R. Franceschini[67,68], R. Franqueir
R. Gargiulo[42], C. Garion[1], M. V.
E. Gianfelice-Wendt[13], S. Gibson[7],
A. Gorzawski[73,1], M. Greco[68], C.
C. Han[75], T. Han[76], J. M. Haupt
S. Homiller[78], S. Jana[79], S. Jindaria
R. Kamath[80], A. Kario[64], I. Karpo
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P. Li[88], Q. Li[89], T. Li[90], W. Li[91],
A. Lombardi[1], S. Lomte[30], K. L
D. Lucchesi[35,10], T. Luo[3], A. Lupat
T. Madlener[74], L. Magaletti[96,44],
C. Marchand[23], F. Mariani[22,42], S. M
A. Mazzolari[24,99], B. Mele[11], F. Mel
D. Moll[55], A. Montella[101], M. Mo
F. Nardi[35], D. Neuffer[13], D. New
J. Osborne[1], S. Otten[64], Y. M. O
M. Palmer[27], A. Pampaloni[28], P.
A. Passeri[68], N. Pastrone[9], A. Pelle
K. Potamianos[17], J. Potdevin[106,1], S.
E. Radicioni[44], R. Radogna[51,44],
C. Riccardi[34,4], S. Ricciardi[29], T.
K. Ronald[86,38], B. Rosser[18], C. R
Queiroz[104,111], S. Saini[47,1], F. Sala
C. Santini[22], A. Saputi[24], I. Sarra

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### 1 Overview of collaboration goals, challenges and R&D programme

The International Muon Collider Collaboration (IMCC) [1] was established in 2020 following the recommendations of the European Strategy for Particle Physics (ESPP) and the implementation of the European Strategy for Particle Physics—Accelerator R&D Roadmap by the Laboratory Directors Group [2], hereinafter referred to as the the European LDG roadmap. The Muon Collider Study (MuC) covers the accelerator complex, detectors and physics for a future muon collider. In 2023, European Commission support was obtained for a design study of a muon collider (MuCol) [3]. This project started on 1st March 2023, with work-packages aligned with the overall muon collider studies. In preparation of and during the 2021–22 U.S. Snowmass process, the muon collider project parameters, technical studies and physics performance studies were performed and presented in great detail. Recently, the P5 panel [4] in the U.S. recommended a muon collider R&D, proposed to join the IMCC and envisages that the U.S. should prepare to host a muon collider, calling this their “muon shot”. In the past the U.S. Muon Accelerator Programme (MAP) [5] has been instrumental in studies of concepts and technologies for a muon collider.

#### 1.1 Motivation

High-energy lepton colliders combine cutting edge discovery potential with precision measurements. Because leptons are point-like particles in contrast to protons, they can achieve comparable physics at lower centre-of-mass energies [6–9]. However, to efficiently reach the 10+ TeV scale recognized by ESPP and P5 as a necessary target requires a muon collider. A muon collider with 10 TeV energy or more could discover new particles with presently inaccessible mass, including WIMP dark matter candidates. It could discover cracks in the Standard Model (SM) by the precise study of the Higgs boson, including the direct observation of double-Higgs production and the precise measurement of triple Higgs coupling. It will uniquely pursue the quantum imprint of new phenomena in novel observables by combining precision with energy. It gives unique access to new physics coupled to muons and delivers beams of neutrinos with unprecedented properties from the muons’ decay. Based on physics considerations, an integrated luminosity target of $10\,\mathrm{ab}^{-1}$ at 10 TeV was chosen. However, various staging options are possible that allow fast implementation of a muon collider with a reduced collision energy or the luminosity in the first stage and reaches the full performance in the second stage.

In terms of footprint, costs and power consumption a muon collider has potentially very favourable properties. The luminosity of lepton colliders has to increase with the square of the collision energy to compensate for the reduction in $s$-channel cross sections. Figure 1.1 (right panel) compares the luminosities of the Compact Linear Collider (CLIC) and a muon collider, based on the U.S. Muon Accelerator Programme (MAP) parameters [7], as a function of centre-of-mass energy. The luminosities are normalised to the beam power. The potential

**Fig. 1.1:** Left: Conceptual scheme of the muon collider. Right: Comparison of CLIC and a muon collider luminosities normalised to the beam power and as a function of the centre-of-mass energy.

4

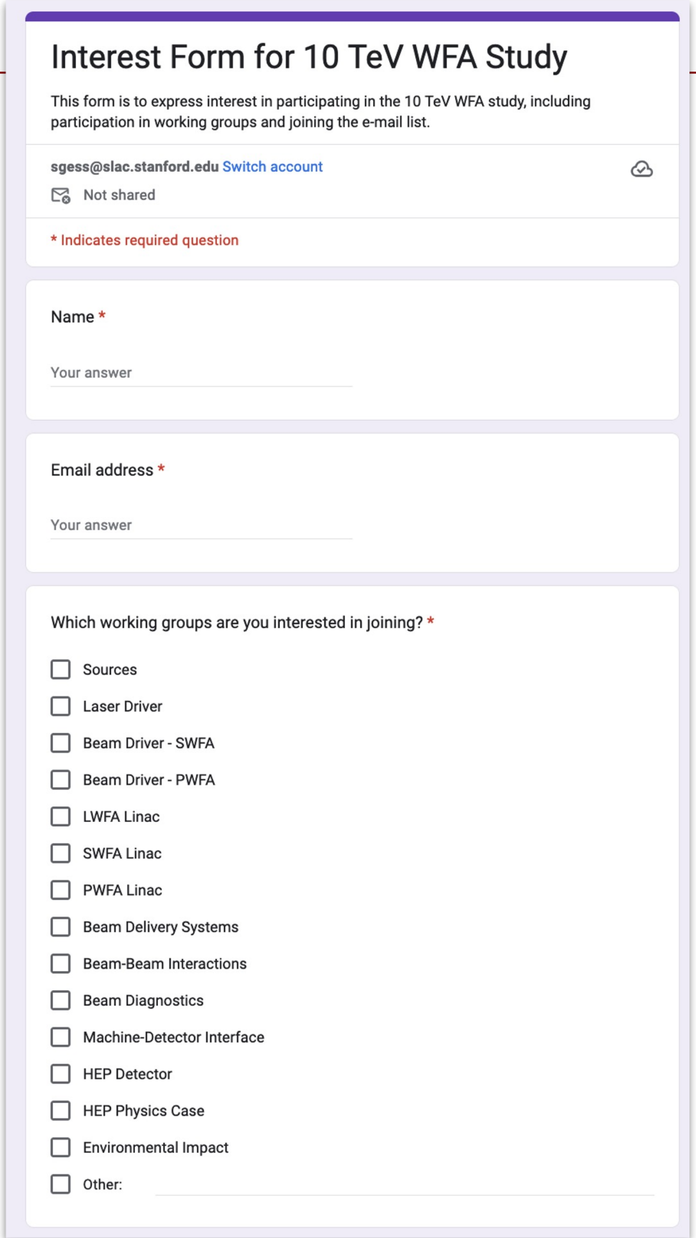
https://arxiv.org/pdf/2407.12450

# Google Form for Study Interest

We are seeking input from the HEP community.

Use the Google Form to indicate your interest and be invited to future meetings!

[https://forms.gle/tLCYykFRdYus7CS86](https://forms.gle/tLCYykFRdYus7CS86)



Interest Form for 10 TeV WFA Study

This form is to express interest in participating in the 10 TeV WFA study, including participation in working groups and joining the e-mail list.

**sgess@slac.stanford.edu** Switch account

Not shared

* Indicates required question

Name *

Your answer

Email address *

Your answer

Which working groups are you interested in joining? *

- ☐ Sources
- ☐ Laser Driver
- ☐ Beam Driver - SWFA
- ☐ Beam Driver - PWFA
- ☐ LWFA Linac
- ☐ SWFA Linac
- ☐ PWFA Linac
- ☐ Beam Delivery Systems
- ☐ Beam-Beam Interactions
- ☐ Beam Diagnostics
- ☐ Machine-Detector Interface
- ☐ HEP Detector
- ☐ HEP Physics Case
- ☐ Environmental Impact
- ☐ Other:

# Advertisement: Postdoc Positions at SLAC

## Research Associate in Beam-Beam Effects for Circular Colliders

SLAC is seeking qualified scientists to contribute to beam-beam studies for the FCC-ee and EIC colliders. These studies will utilize state-of-the-art simulation tools including XSuite, WarpX, BeamBeam3D, BMAD, and the Blast toolkit. Study topics include the beamstrahlung-induced 3D flip-flop instability at FCC-ee and polarization preservation with beam-beam interactions at the EIC.

## Research Associate in the 10 TeV Wakefiled Collider Design Study

SLAC is seeking qualified scientists to contribute to the design of a very high energy future collider based on wakefield accelerator technology. Study topics include staging of plasma accelerators, advanced beam delivery systems, beam-beam interactions with extreme beamstrahlung, and overall system optimization. Participation in the FACET-II experimental program is encouraged.

Postdoc positions will be posted in October. I will forward them to seminar organizers.

# Conclusion

The P5 Report and the broader HEP community call on us to deliver an End-to-End Design Study of 10 TeV pCM collider based on WFA technology.

AAC will meet this challenge as a community!

What is needed for the study to be successful?

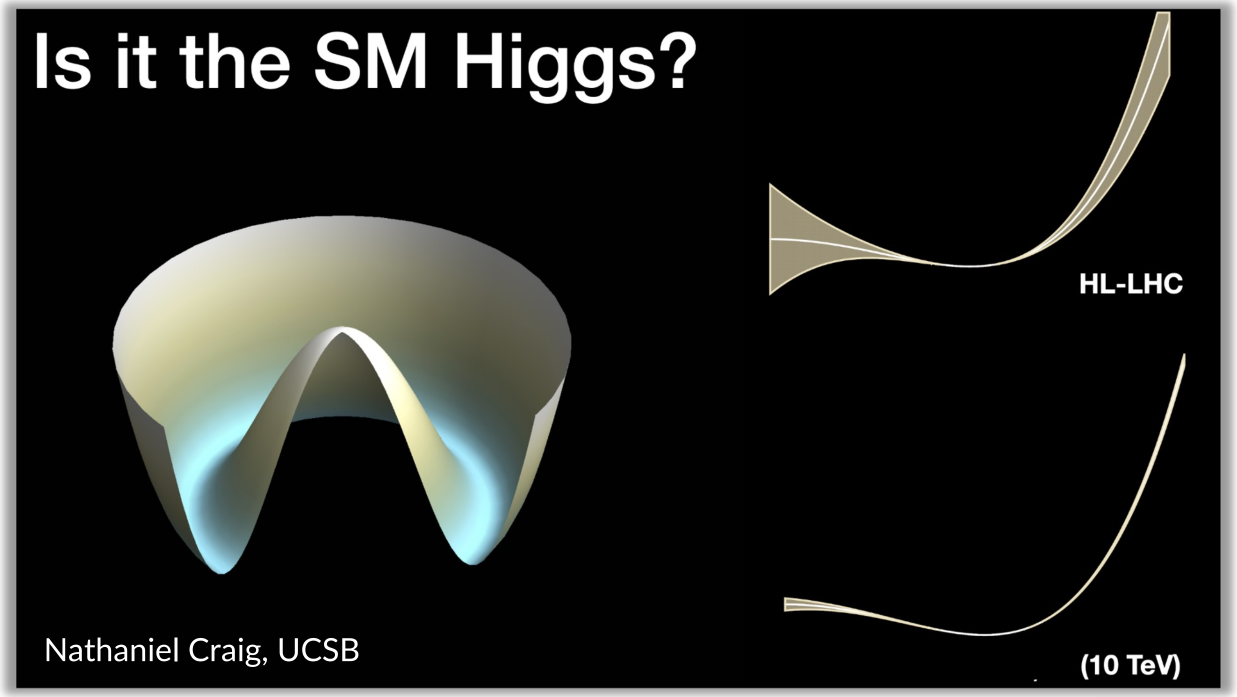
- Engagement with the HEP community.
- Engagement with accelerator physicists with background in colliders.

What does our final product look like?

- A self-consistent, unified concept that specifies the flavor of particle collisions ($e^+e^-$, $e^-e^-$, $\gamma\gamma$) that satisfy the energy and luminosity requirements.
- One or more accelerator designs that provide the necessary beam parameters.

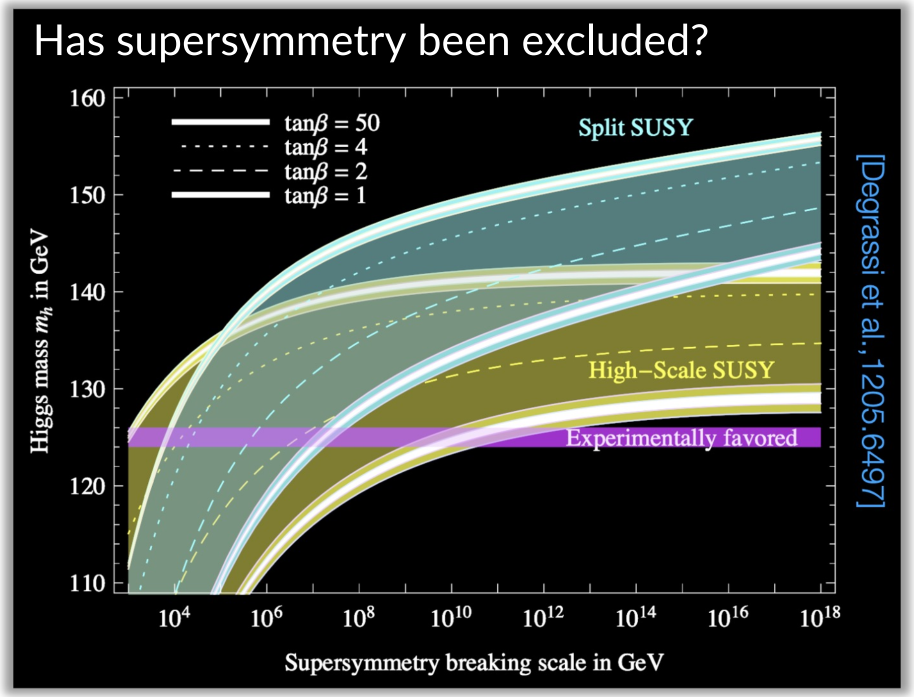
# Backup

# First: Why 10 TeV?



Is it the SM Higgs?

Nathaniel Craig, UCSB



Has supersymmetry been excluded?

[Degrassi et al., 1205.6497]

A 10 TeV pCM collider is a discovery machine that will allow us to explore nature at energy scales far beyond the capabilities of the LHC.